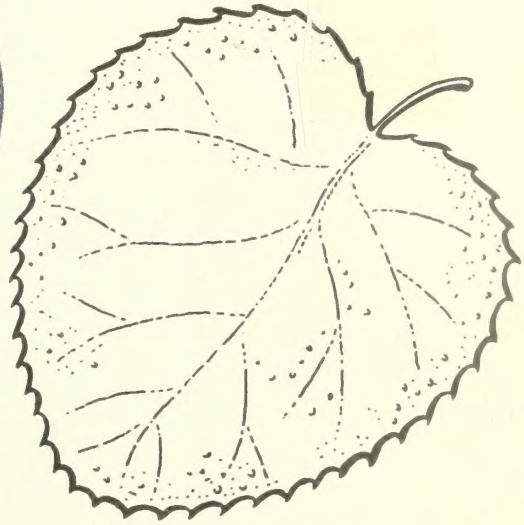
SDA Forest Service General Technical Report SE-11 March 1977

Conference on Endangered Plants in the Southeast

PROCEEDINGS



Betula uber

May 11-13, 1976
Asheville, North Carolina

Forest Service - U.S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

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Sponsored by
Southeastern Forest Experiment Station
USDA Forest Service

University of North Carolina-Asheville

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CONTENTS

OBJECTIVES OF THE CONFERENCE

James D. Perry[1/]

It is obvious from the program that this conference is not an attempt to derive another list of plants which are endangered in one way or another. Rather, it is an effort to arrive at some ways of standardizing our screening procedures and research priorities. It is generally agreed that we must strengthen and broaden our knowledge of plant distributions, of habitat preferences, of population dynamics, and of species biology in general. Although we all have some built-in notion of what species are rare or endangered in our areas, we need some workable definitions to use in classifying these, and the first two papers concern this.

Subsequent papers explore federal and state legislation affecting our actions and the question of propagation and commercial exploitation of endangered plants, such as the Venus' fly-trap.

In the second session, five papers concern preservation of sufficient suitable habitat--natural areas or even whole communities--and on what bases such areas may be considered worthy of preservation. The remaining papers present research needs, dealing with what botanists should do to expand knowledge of species biology and distribution. This is a pressing need of professional foresters and others who manage public lands. In order to manage public lands in such a way as to preserve areas critical to given species, field personnel need to know what these species are and what their requirements are. In addition, field personnel may lack the time or training to identify plants limited in distribution. An efficient means of inventory, storage, and retrieval of information is needed.

Some of the questions we must face, and hopefully reach some consensus about, are: 1) How may we categorize endangered species in a realistic and consistent way from state to state so future legislation will have teeth in it? 2) What are the best ways to preserve rare, endangered, and endemic species? 3) What research approaches do we need in order to establish priorities as time runs out?

This conference was also envisioned as a means of communicating, so that we from various states can find out what those in other states are doing and the different problems being faced.

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DEFINITION AND CLASSIFICATION OF ENDANGERED AND THREATENED PLANT SPECIES

James F. Matthews[1]

Abstract -- Definitions and categories of classification for endangered and threatened vascular plants, as determined by the N.C. Endangered and Threatened Plant Committee, are detailed, along with the philosophical guidelines used in producing a primary list of rare species and a secondary list of endangered and threatened peripheral species.

The definition and classification of endangered and threatened species is the heart of any successful effort in conservation and protection. Everyone interested in endangered and threatened species has probably been frustrated by plans, programs, definitions and lists which often complicate the situation rather than improve it. We of the North Carolina Endangered and Threatened Plant Committee (The Committee is listed at the end of this paper.) have felt this same frustration. While meeting to prepare a report for a state-wide Symposium on Endangered and Threatened Biota in November 1975, we decided to make some decisions, right or wrong, to initiate positive action toward conservation and protection.

We had to analyze those species to be included, define the categories and evaluate the current status of each species all in the context of the long range process of conservation. The full text of that Symposium is being published by the North Carolina State Museum of Natural History and will be available through the Museum.

What I want to do today is to discuss some of the definitions and categories, and to give some of the philosophical concepts used in reaching decisions. First, it is important to recognize that each state cannot independently develop a list of endangered and threatened species now that the Federal Government has published a list through the Smithsonian Institution (1974) and through the Department of Interior Fish and Wildlife Service (1975). Every state list should be so carefully compiled that it would stand up in court, as it will be tested in the halls of the State Legislature. Inclusion of all the popular wildflowers produces a list that cannot be defended, ends up being riddled, thus losing its veracity. How do you defend the query "But the Federal List has only 88 species for our state and yours has 320, why the discrepancy?" We were committed to generating a defendable primary list of species, realizing that many of the showy, dramatic, and peripheral species would be omitted. Because of this, we also developed a secondary list of endangered and threatened peripheral species. Developing different lists with the possibility of various levels of concern dictates different laws to govern each category, an aspect that will be discussed in a later paper.

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Finally, we tried not to become involved in the futile exercise of perserving names. As Core (1955) so aptly said it, "Diversity is not merely subjective or superficial. It is the result of fundamental discontinuity of genetic systems." We wanted to recognize the diversity in the North Carolina flora as realistically as possible. Our basic reference was the Manual of the Vascular Flora of the Carolinas (Radford et al, 1968), and our nomenclature, for the most part, follows their interpretation. We included 91 species in the primary list. Some of these are hybrids, and some have infraspecific designations. Chance hybrids were not included, but species of well documented ancient hybrid origin, such as Wright's cliff-break fern (Pellaea X wrightiana Hooker) and the Tennessee bladder fern (Cystopteris X tennesseensis Shaver) were included because they represent distinct species of no less concern than those derived by other mechanisms. Spontaneous hybrids, even though given a binomial name such as Habenaria X andrewsii White ex Nile or Lysimachia X radfordii Ahles, however rare, were not included, especially since the parental gene pools are known.

In the infraspecific category, we wanted to recognize any gene pool designated as a subspecies or variety which fit our criteria for species included on the list, i.e. Mountain paper birch (Betula papyrifera var. cordifolia (Regel) Fernald). The degree of taxonomic discontinuity is not as important as genetic discontinuity. Whether we, as taxonomists, call something a species, subspecies or variety is insignificant if we are concerned with preserving unique genotypes.

We accepted the Smithsonian definition of endangered and threatened as a working model, with some modifications: Endangered: An endangered species is one whose survival in North Carolina is known to be in serious jeopardy. Its peril may result from destruction or drastic modification of its specific habitat, over-exploitation by man, disease, predation, or specific competition due to natural succession. An endangered species must receive protection, or extinction in North Carolina probably will follow. Threatened: A threatened species is one that may likely become endangered if its habitat is not maintained, or if it is greatly exploited by man. These are often quite rare in North Carolina and should be monitored continuously. They must receive protection within the state.

Defining the term rare is quite difficult, because rareness involves two variables, first the overall distribution and second the relative density or frequency of individual plants within that distribution. The limits of both variables are entirely subjective. A species, i.e., Bladen buttercup (Ranunculus subcordatus E. O. Beal), may be rare because it is represented by very few individual plants and is restricted to a limited geographical area. Another, the Lewis' heart leaf (Hexastylis lewisii (Fernald) Blomquist & Oosting) may be rare because it occurs over a fairly broad range but is in very low density, while another, the Oconee bells (Shortia galacifolia T. & G.), may be rare because of a very limited total distribution within which it is locally abundant. Characterizing species as being rare depends on the interpretation of these variables. Additionally in North Carolina, we found that species are rare because they may be long range disjuncts or endemics, or they may be at the periphery of their range.

A long range disjunct is a rare segment of a species population which is significantly separated from the main area of distribution. Wright's cliff-break (P. X wrightiana Hooker) is now reported from two sites in the North Carolina Piedmont, but is nearly 1,000 miles east of its normal range in the southwestern United States.

An endemic is a species which has its native area totally confined to a small area of North Carolina, and possibly adjacent neighboring states. For a strict North Carolina endemic, Mountain golden heather (Hudsonia montana Nuttall) can be cited; for an endemic extending into a neighboring state, the Venus' fly-trap (Dionaea muscipula Ellis), occurring in three counties of South Carolina, is an example.

An extinct species is one which was endemic in earlier times but is no longer found. The Bigleaf scurfpea (Psoralia macrophylla Rowlee ex Small) was collected only once in 1897 in Polk County. An extirpated species is a disjunct or peripheral species which is no longer found in North Carolina but still occurs elsewhere. Sweet gale (Gale palustris (Lam.) Chev.), a disjunct from Pennsylvania northward, did occur in Henderson County.

Peripheral species may be fairly common north, west and south, but rare at the terminus of their distribution in North Carolina. These native peripheral species represent an integral part of the North Carolina flora. Their elimination here may represent a significant reduction in the gene pool of that species. The Palmetto palm (Sabal palmetto Lodd. ex Schultes) provides a good example of this. In fact, we have included 319 species in the secondary list of endangered and threatened peripheral species.

Exploitation is also a threat to some species. Ginseng (Panax quinquefolium L.), Goldenseal (Hydrastis canadensis L.) and Venus' fly-trap (D. muscipula Ellis) all face the problem of over-zealous collecting. Often, labelling a species as rare hastens its destruction as enthusiasts rush to "protect" it by transplanting into gardens. Management, to permit survival in nature, does not always mean leaving it alone. The necessity for periodic burning to maintain the population competitiveness of pitcher plants (Sarracenia sp.) is a prime example.

Combining the reasons for rareness with the concepts of endangered and threatened permits eight categories. Value judgments must then be made as to the proper category for each species. Table 1 shows a portion of the designations of the 91 species of primary concern. It should be pointed out that the category of a particular species can change as additional information becomes available. Note that exploited species carry double designations. If an extinct or extirpated species is ever found, it will automatically be transferred to the endangered category.

As noted above, the primary list contains 91 species (2.7% of the vascular flora) and the secondary peripheral list, 319, for a total of 410 rare species of native vascular plants in North Carolina. This total represents 12% of the total vascular flora. These lists are different from those compiled by the Smithsonian Institution in 1974, the North Carolina

Table 1. -- Categories of extinct, endangered, threatened and exploited vascular plants

		Extinct	End. endemic	End. throughout	End. disjunct	Thr. endemic	Thr. throughout	Thr. disjunct	Exploited
Carex biltmoreana	Biltmore sedge			X					
Cladrastus lutea	Yellowood						X		X
Dionaea muscipula	Venus' fly-trap					X			X
Eriocaulon lineare	Linear pipewort							X	
Gale palustris	Sweet gale	X							
Geum radiatum	Spreading avens		X						
Sedum rosea	Roseroot				X				

Department of Natural and Economic Resources in 1973, and the North Carolina Garden Clubs and North Carolina Wild Flower Preservation Society. We are not saying that these lists are wrong or that these species are the only ones worthy of preservation. We need to be concerned with the preservation of all 3,400 species of vascular plants in the state. The list is incomplete, but will be updated with additions, deletions, changes of status, and additional county distributions.

N.C. Endangered and Threatened Plant Committee:

J. W. Hardin, Chm., N.C. State Univ.
R. L. Kologiski, N.C. State Univ.
J. R. Massey, UNC-Chapel Hill
J. F. Matthews, UNC-Charlotte
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A. E. Radford, UNC-Chapel Hill

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DEFINITION AND CLASSIFICATION OF ENDANGERED AND THREATENED PLANT SPECIES

Thomas M. Pullen 1/

Abstract.--Suggestions are proposed for dealing with the ambiguities which exist in definitions of terms used to describe the relative abundance of plant species.

Additional keywords: Rare plants.

During the last few years scientists, government officials and agencies, and informed citizens have become more and more concerned about the increasing rate of extinctions among extant species of plants. This has focused attention on the necessity for taking inventory and evaluating the status of those species which still remain, and to develop workable conservation plans for those found to be endangered.

Many efforts toward this end have been launched in recent years. Some have been at the state level, others on a regional basis, and as a result of the passage by Congress of the Endangered Species Act of 1973, Public Law 93-205, at the national level. One of the difficulties encountered in such efforts has been, and still is, adequate definition of what constitutes a rare and/or endangered species. The major purpose of this paper is to have a look at this problem.

DISCUSSION

We find the literature replete with terms describing the relative abundance or the status of plant species. Among those most frequently encountered are common, uncommon, rare, sporadic, threatened, endangered, and extinct. There is little disagreement as to the meaning of the term extinct. When repeated searches of sites where a plant once grew and of nearby similar habitats fails to uncover the plant, there can be little disagreement that the plant no longer exists. On the other hand, definitions of the other and similar terms are very inexact. A species that is considered common in North Carolina might be rated as rare in Mississippi. Most botanists usually consider a species rare when the plants exist in small numbers or when they are few and widely separated. This situations exists either because there have never been many of these plants on the earth or they have reached their present status due to depredations of man or other animals or disease. In any case rare plants, by their very nature should be considered threatened or endangered.

The author suggests the adoption of the definitions set forth in the Endangered Species Act of 1973 for those species we are most concerned about. Therein we find the two terms "endangered" and "threatened." Endangered species are defined as "those in danger of extinction throughout all or a significant portion of their ranges." Threatened species "are those which are likely to become endan-

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gered within the foreseeable future throughout all or a significant portion of their ranges." The law establishes the following criteria for determining whether a species should be listed as an endangered species:

1. "The present or threatened destruction, modification, or curtailment of its habitat or range;

2. Overutilization for commercial, sporting, scientific or educational purposes;

3. Disease or predation;

4. The inadequacy of existing regulatory mechanisms; or

5. Other natural or man-made factors affecting its continued existence."

We are all familiar with the list of endangered, threatened, or extinct plant species of the United States prepared by the Smithsonian Institution as a result of the passage of the Endangered Species Act. We are also grateful for the tremendous effort that went into this undertaking. There can be no doubt of the value of such a national effort but the author believes that state and local lists are also very important. Locally imperiled species should be preserved even though they may be abundant elsewhere.

A REVIEW OF THE ENDANGERED SPECIES ACT OF 1973

James D. Williams and Gail S. Baker

OFFICE OF ENDANGERED SPECIES AND INTERNATIONAL ACTIVITIES

U.S. FISH AND WILDLIFE SERVICE

WASHINGTON, D.C.

The Endangered Species Act of 1973 is the strongest legislation ever enacted to protect Endangered and Threatened plants and animals. The Act gives the Department of Commerce and the Interior regulatory and statutory authority on Endangered and Threatened fauna and flora. The 1973 Act provides for two categories of species listing, Endangered and Threatened, as opposed to one category, Endangered, in the 1969 Act. Also new are provisions for State cooperation and participation in the program through cooperative agreements, grants-in-aid funding, and other incentives. The 1973 Act calls for participation where appropriate by all Federal Agencies and directs that no Federal funds can be utilized for an activity that would be detrimental to an Endangered or Threatened species.

This presentation is based on a reveiw of the Endangered Species Act prepared by the staff biologists of the Office of Endangered Species and International Activities. The Endangered Species Act of 1973 (hereinafter referred to as the Act) was passed by the 93rd Congress and signed into law by the President of the United States on December 28, 1973. The Act is the strongest legislation ever enacted to preserve and protect Endangered and Threatened animals and plants. The Act expands upon previous acts on Endangered species, the most recent being the Endangered Species Conservation Act of 1969. The 1973 Act provides for two categories of species listing, Endangered and Threatened, as opposed to one previous category of endangered in the 1969 Act. It allows for listing on a population basis for animals of any group. Also new are provisions for State cooperation and participation in the program through cooperative agreements, grants-in-aid funding, and other incentives. The new Act calls for participation where appropriate by all Federal agencies and directs that no Federal funds can be utilized for an activity that would be detrimental to an Endangered species.

The Endangered Species Act of 1973 is a very complex piece of legislation and has frequently led to confusion and various erroneous interpretations. The following is a brief review of the Act section by section to point out some of the more important features of the Act. The following paper by Baker and MacBryde explains the provisions of the Act for plants.

Section 2. Findings, Purposes, and Policy

Section 2 presents the reasons for the Act. Because of man's activities, species of wildlife have become extinct and other species are presently

faced with the threat of extinction. Recognized are the educational, scientific, recreational, historical and esthetic values of endangered and threatened species. The need for protection of Endangered species and Threatened species is a world-wide problem and has been recognized by international treaties and conventions. The Act provides a tool to implement international commitments. The States and other interested parties are an integral part of the program to meet both national and international needs for protection of wildlife. Through Federal financial assistance and other incentives State participation is to be encouraged.

The purposes of the Act are to conserve the ecosystems upon which Endangered and Threatened species depend, and provide a program for the conservation of such species. The Act also insures that the U.S. lives up to the international treaties and conventions on conservation to which it is a party. Finally, Congress declared that it was their policy that all Federal departments and agencies should seek to conserve Endangered and Threatened species and should utilize their authorities in furtherance of the purpose of the Act.

Section 3. Definitions

There are 16 terms which are defined for the purposes of the Act. Selected definitions of terms whose meanings are important keys to interpretation of certain sections of the Act are as follows:

(2) The terms "conserve," "conserving," and "conservation" mean to use and the use of all methods and procedures which are necessary to bring and Endangered species or Threatened species to the point at which the measure provided pursuant to this Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking. To most wildlife managers, the term conserve as used in the Act means management.

(4) The term "Endangered species" means any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present overwhelming and overriding risk to man.

(5) The term "fish and wildlife" means any member of the animal kingdom, including without limitation any mammal, fish, bird (including any migratory, or endangered bird for which protection is also afforded by treaty or other international agreement), amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate, and includes any part, product, egg, or offspring thereof, or the dead body or parts thereof.

(9) The term "plant" means any member of the plant kingdom, including seeds, root, and other parts thereof.

(11) The term "species" includes any subspecies of fish or wildlife or plants and any other group of fish or wildlife of the same species or smaller taxa in common spatial arrangement that interbreed when mature.

(14) The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

(15) The term "Threatened species" means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Section 4. Determination of Endangered and Threatened Species

Section 4 provides for the determination of Endangered and Threatened species. The determination of a species as "Endangered" or "Threatened" is based upon one or more of the following factors:

(1) The present or threatened destruction, modification, or curtailment of its habitat or range;
(2) Overutilization for commercial, sporting, scientific, or educational purposes;
(3) Disease or predation;
(4) The inadequacy of existing regulatory mechanisms; or
(5) Other natural or man-made factors affecting its continued existence.

The Secretary of Commerce bears the prime responsibility for the determination of Endangered or Threatened marine species. The Secretary of the Interior has the responsibility for all other species, plus the actual determination process for all species. The procedures involved are detailed in the flow chart in Figure 1.

When species are determined to be Threatened, regulations that are necessary for protection and management may be issued by the Secretary. However, it may not be necessary to issue any regulations for some species. The Secretary can issue regulations that prohibit any act that is promulgated under Section 9 of the Act. An exception to this is when a State has entered into a cooperative agreement, than only those regulations which have been adopted by the State for taking threatened resident species of wildlife shall apply.

When a species is similar in appearance to an Endangered or Threatened species, regulations can be issued for this species to insure protection of the Endangered or Threatened species. The reasons for this are to avoid difficulties of identification by law enforcement personnel, prevent additional threats to Endangered or Threatened species and further the intent of the Act.

All regulations by the Secretary will be published in the Federal Register after consultation with appropriate State and Federal agencies and interested persons and organizations.

FIGURE 1 GENERAL PROCEDURES FOR
MODIFYING LISTS OF THREATENED OR ENDANGERED SPECIES

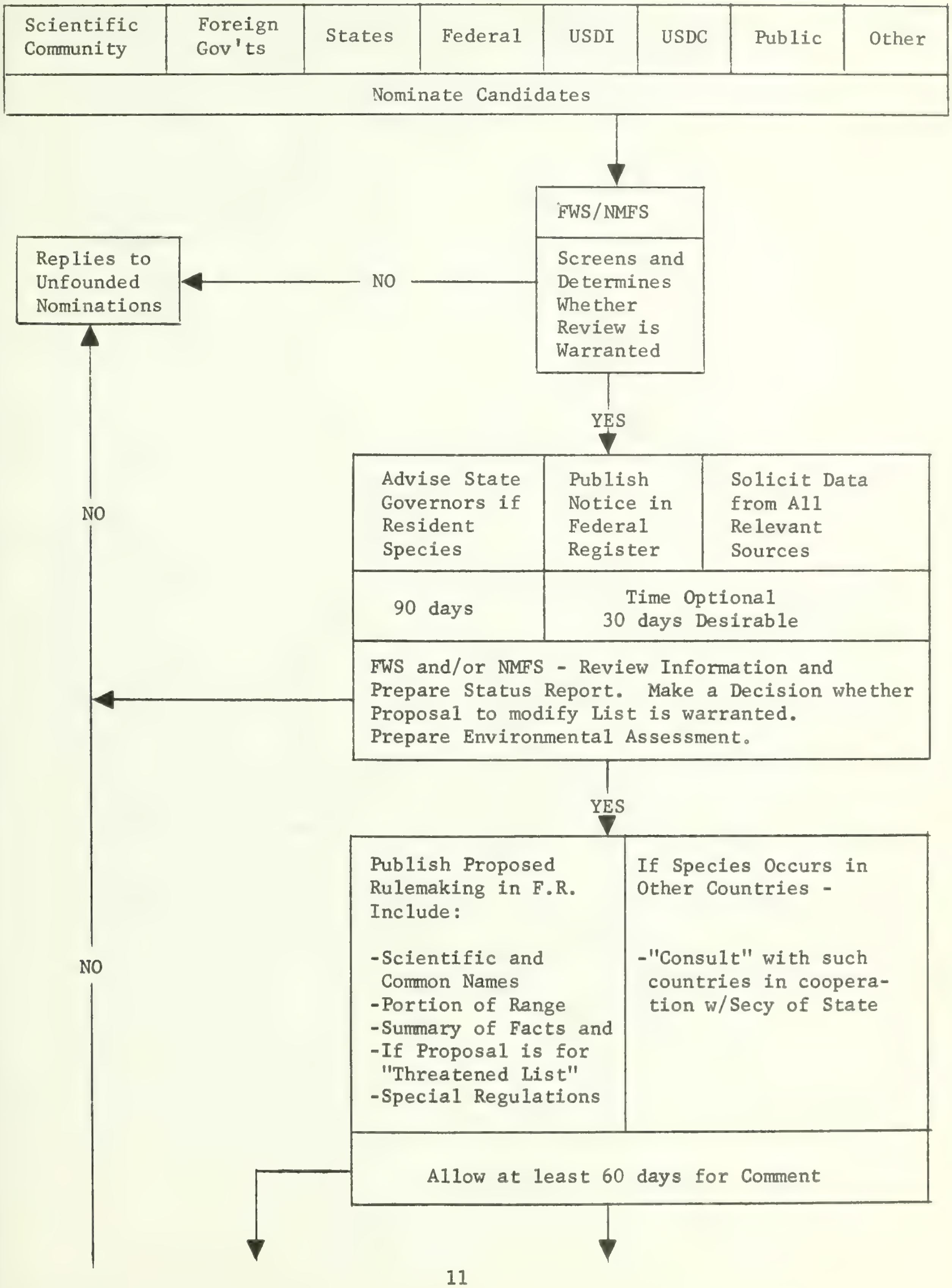
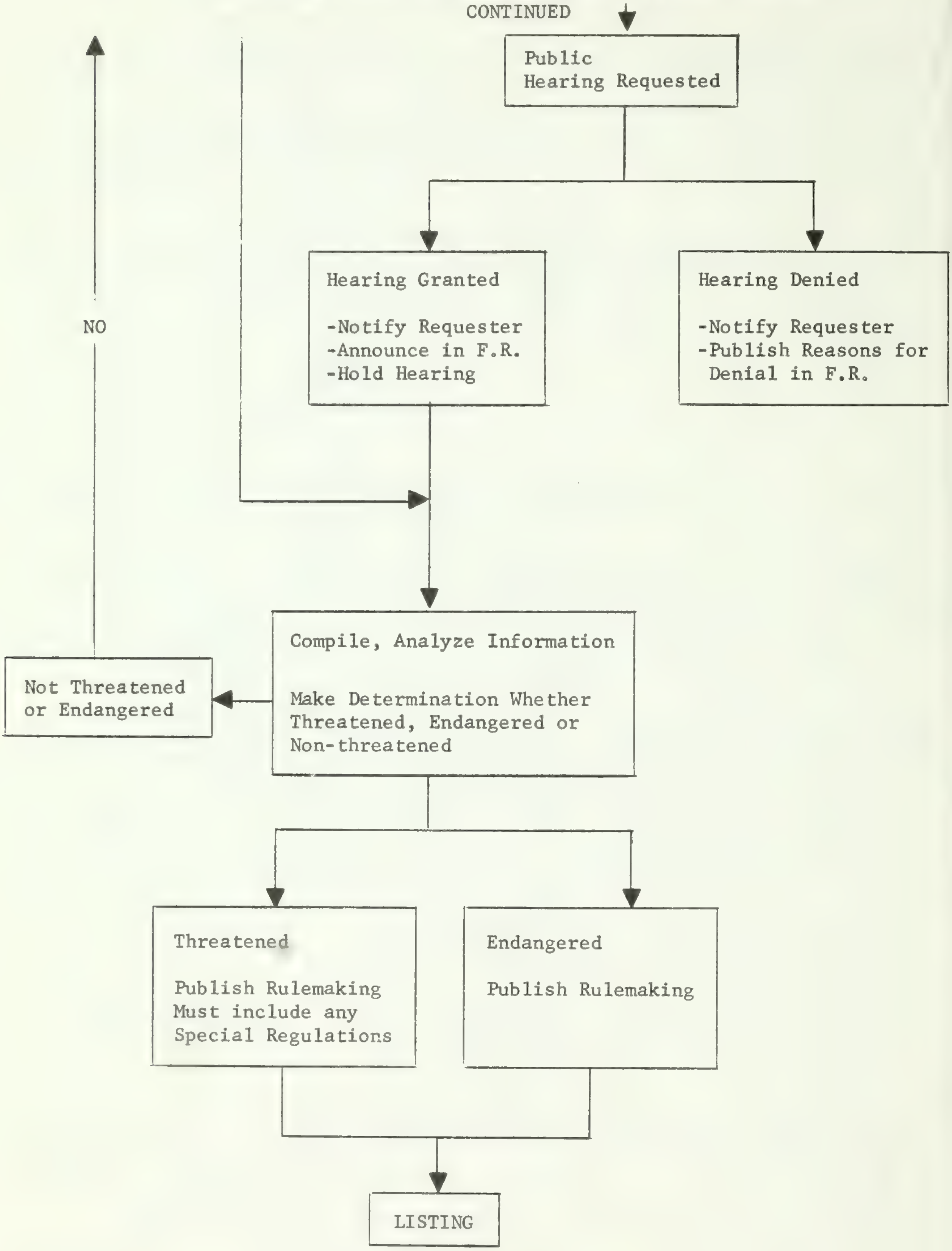


FIGURE 1 GENERAL PROCEDURES FOR MODIFYING LISTS OF THREATENED OR ENDANGERED SPECIES CONTINUED



At the present time (April 1976) the official list contains a total of 427 Endangered species and 11 Threatened species of both foreign and domestic origins. Of the 427 species, 147 are Endangered or Threatened species found in the U.S. and its territories. The present U.S. lists of Endangered and Threatened species includes 33 mammals, 66 birds, 8 reptiles 4 amphibians, 34 fishes, and 2 insects. The list does not include all of the species found in the U.S. Fish and Wildlife 1973 Red Book. It is anticipated that the restructuring of the list should occur within the next year. There are no plants on the list at this time.

Section 5. Land Acquisition

This section authorizes acquisition of land and water habitat for Endangered and Threatened species using Land and Water Conservation funds. This provision was also present in the 1966 and 1969 Acts. To date more than 40,000 acres of habitat for 11 Endangered species has been acquired at the cost of approximately 13 million dollars.

Section 6. Cooperation with States

This section of the Act recognizes the need for close cooperation with the States and provides for management agreements and cooperative agreements to assist the States with their programs. Management agreements between States and the Fish and Wildlife Service provide for administration and management of areas established for the conservation of Endangered species or Threatened species. In cases where conflicts arise between State and Federal laws or regulations, the more restrictive laws or regulations shall apply.

Cooperative agreements, among other things, provide for Federal assistance to the States for implementation of State Endangered and Threatened species programs. For a State to be eligible for a cooperative agreement with the Fish and Wildlife Service, the State agency must have:

(1) Authority to conserve species that have been determined by the State or the Fish and Wildlife Service to be Endangered or Threatened. This authority should be broad enough to cover additional species that may be listed in the future.
(2) Acceptable conservation programs for all resident fish or wildlife species in the State that has been determined to be Endangered or Threatened by the U.S. Fish and Wildlife Service.
(3) Authority to conduct investigations.
(4) Authority to acquire land or aquatic habitats for conservation of resident Endangered and Threatened species.
(5) Provisions for public participation in designating resident Endangered species or Threatened species.

Cooperative agreements provide for 1) the actions that are to be taken by the Secretary and the States, 2) the benefits that are expected to be derived by the cooperative program, 3) the estimated cost of the actions, and 4) the share of the costs by the Federal Government and the States. The Federal share shall not exceed two-thirds of the estimated program costs; however, this share can be increased to 75% for species shared by two or more States.

Review of the State's programs must be made at least annually to assure that their programs are effective and that legal authorities are still appropriate.

Section 7. Interagency Cooperation

Section 7 charges the Secretary to review all Department of Interior programs and to use these programs for furtherance of the Act. All other Federal agencies in consultation with the Secretary and his assistants, are to utilize their authorities in furtherance of the Act by carrying out programs for the conservation of Endangered and Threatened species. These agencies are also to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of these species or result in the destruction or adverse modification of habitat that is determined to be critical for them by the Secretary after consultation with the affected States.

Section 8. International Cooperation

This section provides for international programs for Endangered animal and plant species. Among other items, this section provides the mechanics for financial assistance, encouragement of foreign programs, personnel, investigations, and implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Section 9. Prohibited Acts

Two important prohibitions under the Act make it unlawful for any person subject to the jurisdiction of the United States to take any Endangered fish or wildlife species within the United States or the United States Territorial Sea (take means harass, harm, pursue, hunt, shoot, kill, trap, capture, or collect, or attempt to engage in any such activity), and to violate any of the regulations that may be promulgated by the U.S. Fish and Wildlife Service for Threatened fish or wildlife species. It is also unlawful for any person to violate regulations promulgated by the Secretary on Threatened plant species. The Act does not prohibit the "taking" of Endangered or Threatened plant species.

Section 9 also deals with Endangered and/or Threatened species held in captivity, with violations of the Convention, and with import/export only via official ports designated.

Section 10. Permits

Permits may be issued by the Fish and Wildlife Service that would allow certain actions that are prohibited under the Act (e.g., taking of Endangered and Threatened species of fish and wildlife). These permits are issued for scientific purposes or for propagation or survival programs that would enhance the species. An application for a permit must be filed with the U.S. Fish and Wildlife Service which then reviews and publishes the application in the Federal Register for a 30-day period. If no valid, adverse biological comments are received, the permit is then issued to the individual that will be conducting the programs or activities.

Section 11. Penalties and Enforcement

Section 11 expresses the civil penalties that can be assessed by the Secretary on persons who violate the Act. It also covers criminal violations, rewards, district court jurisdiction, and enforcement. It also provides for citizen suits that can enjoin any person, including governmental agencies or instrumentality who is alleged to be in violation of the Act.

Section 12. Smithsonian Institution Report on Plants

Through this section, the Secretary of the Smithsonian Insitution, in conjunction with affected agencies, was directed to review plant species and develop a recommended list and recommendations for conservation of Endangered and Threatened plant species within one year. This information was presented in a report to the Congress in December 1974.

Section 13. Conforming Amendments

This section amends other acts to be consistent with the Endangered Species Act of 1973.

Section 14. Repeal

This section repeals the Endangered Species Conservation Act of 1969.

Section 15. Funding

This section authorizes funding for the Departments of Interior and Commerce to carry out their responsibilities under the Act.

Section 16. Date

This section provides for the effective date of the Act--December 28, 1974.

Section 17. Relationship to Man's Mammal Protection Act

This section states that except as otherwise provided for in the Act, no provision of the Act will take prededence over any more restrictive, conflicting provisions of the Marine Mammal Protection Act of 1973.

This has been a very brief review of the Endangered Species Act of 1973. For additional information, a copy of the Act, various Federal Register documents listing species and critical habitat and general information on Endangered and Threatened species, please contact the Office of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C. 20240

THE ENDANGERED AND THREATENED PLANT PROGRAM

OF THE U.S. FISH AND WILDLIFE SERVICE

Gail S. Baker and Bruce MacBryde

OFFICE OF ENDANGERED SPECIES AND INTERNATIONAL ACTIVITIES

U.S. FISH AND WILDLIFE SERVICE

WASHINGTON, D.C.

The Endangered Species Act of 1973 differs from the 1966 and 1969 Acts by including plants. The Smithsonian Institution prepared a list of 3,187 candidate Endangered and Threatened plant taxa as required by the Act. The U.S. Fish and Wildlife Service accepted this list as a petition in the Federal Register on July 1, 1975. The 45 foreign plant taxa on Appendix I of the Convention Fauna and Flora were published in the Federal Register on September 26, 1975. A major difference between the treatment for plants and animals in the Act is that the "taking" of plants is not regulated, although interstate and international commerce are.

The previous paper by Williams discusses the Endangered Species Act of 1973 (Public Law 93-205) in general terms; this paper explains the provisions of this Act for plants.

Previous Endangered Species legislation (1966 and 1969) did not include plants. In Section 3 of the 1973 Act the term "plants" is defined as "any member of the plant kingdom, including seeds, roots and other parts thereof." Section 2(a)(4) of this Act specifies that the U.S. has pledged itself to conserve the 20,000 plants now listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Section 12 of the 1973 Act directs the Smithsonian Institution to review species of plants which are or may become endangered or threatened and to report to Congress within one year.

There are several major differences in how plants and animals are dealt with in the Endangered Species Act of 1973.

In Section 3, the term "species" is defined as including "any subspecies of fish or wildlife or plants, and any other group of fish or wildlife of the same species or smaller taxa in common spatial arrangement that interbreed when mature." Hence, population segments of animals are included in the Act, whereas population segments of plants are not included.

Section 5 states that land can be purchased for the conservation of Endangered and Threatened wildlife, fish or plants with funds made avail-

able pursuant to the amended Land and Water Conservation Fund Act of 1965. For plants there is the added restriction that they must be included in the Appendices to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. This international convention has been ratified by the United States and over twenty other countries, and came into force on July 1, 1975.

The purpose of the Convention is to reduce the impact of international trade on plants and animals for which this activity is or may become a threat to their survival. These organisms are listed, depending on the degree of endangerment, on the three appendices of the Convention. Appendix I, the most seriously jeopardized group of animals and plants, includes only foreign plant taxa, but Appendix II includes the entire orchid and cactus families, both of which have many rare taxa in the United States. Appendix II also includes ginseng (Panax quiquefolius) which is native to North America. Appendix III of the Convention includes no plants as yet, but the United States, as a party to the Convention, can unilaterally add plant species to this Appendix to prevent commercial exploitation.

Section 6 deals with cooperative agreements with States and provisions for financial aid from the Federal government to carry out these cooperative programs. Before a State can enter into a cooperative agreement, it must show that a State agency exists which has the authority to establish programs, including the acquisition of land, for the conservation of resident Endangered and Threatened species. There is some question as the whether Section 6 applies to plants. The Fish and Wildlife Service is seeking authority to permit States to enter into cooperative agreements for whatever Endangered and Threatened species they have authority to conserve. A decision on this matter will be reached shortly.

Section 7 deals with interagency cooperation, and directs all Federal agencies to maintain programs for the conservation of Endangered and Threatened species. It also directs them to insure that actions authorized, funded or carried out by them do not jeopardize the existence of such species or modify Critical Habitat of such species. Section 7 is a major strength of the Act with respect to plants.

Perhaps the most important difference between plants and animals in the Act is that the "taking" of Endangered animals is prohibited, whereas the taking of Endangered plants is not. Section 9 spells out the prohibitions for plants. It will be unlawful to:

(1) import or export such plants to or from the United States;
(2) transport such plants in interstate or foreign commerce; and
(3) sell such plants in interstate or foreign commerce.

Section 9 does not prohibit or regulate;

(1) the intrastate sale of such a plant; and
(2) interstate movement of such plants unless it involves commercial activities which include a change in ownership.

Section 10 provides for exceptions to these prohibitions. Permits will be issued by the U.S. Fish and Wildlife Service, as they are for Endangered and Threatened animals, to carry out prohibited acts for scientific purposes or to enhance the propagation or survival of the affected species.

Section 12, as mentioned earlier, directed the Secretary of the Smithsonian Institution to conduct the initial reveiw of possible Endangered and Threatened plants, and to recommend methods of adequately conserving such species. The Smithsonian Institution was given one year to complete this task, and their "Report on Endangered and Threatened Plant Species of the United States" (House Document 94-51) was presented to Congress on January 9, 1975. This report contains the names of over 3000 plant taxa which are perhaps extinct, or possible endangered or threatened. Over 1000 of these are endemic to Hawaii. Other States with very large numbers of plants included in the report are California, Texas, and Florida.

The Endangered Flora Project within the Department of Botany at the Smithsonian Institution was responsible for preparing the report. Their lists were prepared by reviewing floras, taxonomic monographs and revisions. Also, taxonomic specialists were consulted and some collections were checked in herbaria. State lists of rare and endangered plants were also used as reference material. (The report is not a compilation of State lists, however, since a plant may be extirpated, rare or endangered in one State, but very common in another.) In September 1974, a workshop was held under the joint sponsorship of the Smithsonian Institution and the Office of Endangered Species and International Activities of the U.S. Fish and Wildlife Service. The participants included botanists from Federal agencies, universities and botanical gardens. They reviewed the plants on a preliminary list and refined it; much unpublished data and new distributional information was used during the workshop. Since the Smithsonian Institution report lists plants found basically in the 50 States, species occurring outside the U.S. as well were not included unless their exact endangerment status outside the country was known. Only vascular plants are covered by the Act. (DeFilipps (1976) presented a history of the compilation of the report.)

The Endangered Flora Project at the Smithsonian Institution has continued its work. The lists of plants in the original report have been revised on the basis of comments received both by the Smithsonian and the Fish and Wildlife Service. The revised lists will be published in May or June of 1976. In addition, the Endangered Flora Project personnel are preparing computerized distribution maps of the localities of the exploited plants listed in the report, and computerized information sheets for the plants included in their revised lists. They are also preparing a series of Red Data Book entries of U.S. plants for the I.U.C.N. Red Data Book on Angiosperms. This series includes representatives of different geographical regions, diverse plant families and various kinds of threats.

The U.S. Fish and Wildlife Service regards the Smithsonian Institution's report to be a "petition" as provided for in Section 4(c)(2) of the Act. On July 1, 1975, the Smithsonian Institution's list (plus a few additions and

corrections) was published as a "Notice of Review" in the Federal Register. By publication of this list the Service formally initiated a review of the status of these plants pursuant to the Endangered Species Act of 1973.

Previously, on April 21, 1975, a "Notice of Review" for four plants was published in response to a petition from a group of Wisconsin citizens. Subsequent to the publication of both Notices, the governors of all States and U.S. Territories involved were informed and their comments were solicited. Copies of the July 1 Notice were also sent to many other U.S. government agencies and botanists throughout the country. The 45 foreign plant taxa on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora were published in the Federal Register as a proposed rulemaking on September 26, 1975.

As of May 1976, therefore, over 3200 plants are in the process of being considered for determination as Endangered or Threatened. In the near future, the Fish and Wildlife Service is planning to propose:

(1) regulations that would implement the Act with regard to plants and
(2) a determination that about 1700 plants form the Smithsonian revised report are Endangered pursuant to the Endangered Species Act of 1973.

Both the proposed regulations and the proposed list of Endangered plants will probably be published in the Federal Register by the summer of 1976. A minimum 60-day comment period will follow both proposed rulemakings.

Also, a final rulemaking that determines which of those plants on Appendix I of the Convention are to be classified as Endangered on the U.S. list will probably be published in the summer of 1976.

Obviously, the Endangered Species Act of 1973 offers many possibilities for plant conservation. The help of professionals, such as the participants in this conference, is essential for responding wisely and effectively to the Act. Any data on plants, will be welcomes by the Office of Endangered Species. Details on distribution, threats to survival, propagation techniques and recent taxonomic studies are some of the kinds of information which can help the U.S. Fish and Wildlife Service implement the Endangered Species Act of 1973 on behalf of our plant heritage.

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FEDERAL AND STATE PROGRAMS ON ENDANGERED PLANTS

Frank B. Barick [1/]

Abstract. - Discusses current status of Federal and State laws and programs related to preservation of endangered plants in North Carolina, as well as statutory needs to provide for implementation in North Carolina.

Keywords: Endangered plants, North Carolina, endangered species act, North Carolina Wildlife Resources Commission.

In discussing the subject assigned to me - Federal and State Programs on Endangered Plants - I would like to first briefly review those aspects of the Federal Endangered Species Act relating to plants and recent developments at the federal level in this area. Second, I will discuss the present status of North Carolina laws relating to endangered plants. Third, I will discuss the endangered species program of the North Carolina Wildlife Resources Commission. And fourth, I will briefly discuss future needs for implementing this program.

The Federal Endangered Species Act was passed on December 28, 1973. This was about 2 1/2 years ago. Although the act provided for funding of cooperative programs with the states, no moneys have as yet been released for this purpose. We have received word, however, that such funds will be forthcoming after July 1 of this year.

The general purposes of the Act are succinctly expressed in its introduction and are well worth repeating at this time to help us focus on our mission. The "findings" upon which the Act is based are as follows:

1) Various species of fish, wildlife and plants in the United States have been rendered extinct as a result of economic growth and development untempered by adequate concern and conservation.

2) Other species have been so depleted in numbers as to be faced with extinction.

3) These species are of aesthetic, ecological, educational, historical, recreational and scientific value to the Nation and its people.

As a result of these findings, the United States has pledged itself to conserve to the extent practicable the various species of fish, wildlife and plants faced with extinction.

The Act states that the Federal government shall encourage the states and other interested parties to develop conservation programs designed to conserve endangered species through a system of incentives, i.e. financial support, provided programs so designed meet federal standards.

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It also established the policy that all federal agencies will seek to conserve endangered species and utilize their authorities in furtherance of this act.

The Act provided for the establishment of cooperative agreements with individual states that would fund specific work projects on a 66 2/3- 33 1/3 percent matching basis and required that such work be in accordance with prior-approved work plans. In order to qualify for participation states are required to demonstrate that:

1) The designated state agency has the authority to conserve endangered species.

2) That the designated state agency has an acceptable program of endangered species preservation.

3) That the agency is authorized to conduct investigations to determine the status and needs of endangered species.

4) That the agency is authorized to acquire land and water habitats and manage same.

5) That the agency will provide for public participation in designating endangered species.

Passage of the Federal Act came after several years of investigation and reporting by fish and wildlife biologists and it was only natural that major responsibility for implementation was assigned to the U. S. Fish and Wildlife Service in the Department of the Interior. Because of this early work there was a considerable body of information at hand on the status of faunal species at the time the Act was passed. As a result, it was possible for the Secretary of the Interior to issue an official list of endangered animal species about the same time as the Act was passed. No such list of plants was available, however, and so the Smithsonian Institute was instructed to compile a preliminary list. This was published last year and a proposed official list is scheduled to be published in the Federal Register later this year. We are advised that this list will contain about 1700 species, about half of which are confined to Hawaii and that about 16 occur in North Carolina as endangered and about 48 as threatened. After a 60-day public comment period the Secretary of the Interior will establish an official federal list of endangered plants. He was given authority for such action by an executive order issued in April of 1976 - just last month.

The Act establishes that a species of plant or animal on the Federal list is officially designated as endangered in any state where it occurs but that the state may indicate where in the state it has that status. Also, additional species may be designated as endangered or threatened by the state agency having jurisdiction over endangered species.

Designation of plants as endangered species and establishing regulations for their protection involves legal complications beyond those that surround animals. Since animals can move across property lines, they are owned by the people in severalty, i.e., <u>all</u> of the people of the state. But plants are affixed to the land and so they are legally part of the real estate. Thus,

regulations regarding the preservation of plants could come into conflict with constitutional and legal property rights. For this reason, some landowners are seriously concerned about the enactment of laws relating to endangered species preservation.

Because of this circumstance, that part of the U. S. Fish and Wildlife Service endangered species program related to cooperative funding of state programs is currently restricted to animal species. It is also restricted to inland water and terrestrial forms, i.e. excludes marine forms. Presumably, provision will be made in the near future to include work on plants and marine forms.

At the present time about a dozen states have completed negotiation of cooperative agreements with the U. S. Fish and Wildlife Service and we in North Carolina are now in the process. Certification that the North Carolina Wildlife Resources Commission has the required authorities has been developed with the cooperation of the State's Attorney General and submitted to Washington. Upon receipt of approval of this documentation, we shall proceed with development of a cooperative agreement and detailed work plan and budget.

So much for the status of Federal laws and programs on endangered species. Let us now turn our attention to North Carolina state laws.

To the best of our knowledge, there is only one law on our books that is specifically designed to protect an endangered plant species. This is Section 129.1 of Chapter 14 of the General Statutes which prohibits the sale or barter of venus flytrap and assigns responsibility for enforcement to the Department of Conservation and Development. Section 129 of Chapter 14 prohibits the taking of wild plants from the land of another without permission but does not assign enforcement authority to any agency and 22 counties are exempt from its provisions. This section includes venus flytrap, trailing arbutus, hemlock and 39 other species and groups of species (such as azaleas or coniferous trees).

Laws which give the Wildlife Resources Commission jurisdiction over endangered species make only tangential reference to plants. Thus, before the Commission can become actively engaged in enactment of protective regulations in this area, it will have to be clothed with additional authority by the State Legislature. The North Carolina Game Law is currently under study for revision and we are hopeful that this deficiency will be remedied by the next legislature. We may be calling upon some of you for assistance in this effort at that time and we would hope that you will respond in a positive way.

In this connection it may be appropriate to raise the question as to why the Wildlife Commission, rather than some other state agency, should have this authority. This question was considered during the course of the 1975 Legislature in conjunction with the attempted passage of the "Model State Endangered Species Act" developed by the U. S. Fish and Wildlife Service. At that time it was agreed by various state agencies and members of the Legislature that the Wildlife Resources Commission was the appropriate agency for administration of endangered species conservation for the following reasons:

1) Wild plants constitute part of the habitat and total ecology of wild animals, over which the Commission already has jurisdiction.

2) The Wildlife Commission already has a staff of professional biologists some of whom can specialize in plant species.

3) The Wildlife Commission has a staff of enforcement personnel who routinely patrol areas where endangered plant species grow. These officers can be trained and/or recruited to enforce endangered plant species regulations.

4) The Wildlife Commission has a long history of regulation formulation as regards wild animals and could readily adapt to formulation of regulations relating to wild plants.

5) The Wildlife Commission has had for many years an on-going cooperative program in wild fish and game management with the U. S. Fish and Wildlife Service.

6) The Wildlife Commission has the authorities required by the Federal Endangered Species Act, except that as noted above, it needs to acquire additional authority in regard to wild plants.

We now need to turn our attention for a few moments to the current endangered species program of the Wildlife Commission. Before doing so, however, we should point out that the Commission has, from its establishment in 1947, always exercised a measure of concern for non-game and endangered species. It sponsored legislation protecting hawks and owls, alligators, bobcats and panthers. It has conducted an active youth education program on all wildlife including songbirds and plants. And it has developed an extensive library of brochures and films on various aspects of natural resources conservation.

With the emergence of endangered species as a special area of concern, the Wildlife Commission established a three-phased program geared to take advantage of federal funding as it became available. Phase I, which was initiated last year, undertook development of a list of persons and agencies having interest and professional expertise in the area of endangered species. Many of you in this room responded to our questionnaire and have been entered in our register. If there are others among you who have not been contacted we would be pleased for you to see me about filling out a form outlining your area of interest. Another part of Phase I was the development of a library on endangered plants and animals. Phase I is well along toward completion but we are anxious to add to it as opportunity occurs. It was undertaken with existing staff and funds, and the special cooperation of the N. C. State Museum. We are especially grateful to Museum Director Dr. John Funderburg for his help.

Phase II, which has not yet been initiated, is waiting on federal funds. It will consist of in-depth studies of species on the endangered and threatened lists that occur in North Carolina. Its purpose will be to develop information on the status and distribution of individual species, to identify factors limiting its survival and measures required to ensure its preservation. These studies will be conducted on a contract basis by interested individuals. Perhaps some of you here today may be interested in conducting such studies or you may know of others who would be interested. We shall be pleased to receive study proposals when funds become available.

Phase III will consist of implementation of findings of Phase II. Implementation may take various forms, such as development of management programs,

acquisition of critical habitat, public information, designation of additional species as endangered or threatened, development of regulations relating to taking and/or commercialization of endangered species, and enforcement of regulations. Phase III has to some extent been inplemented, at least in regard to one species - the red-cockaded woodpecker - in that we have developed habitat management procedures for application on our Sandhills Game Lands which constitute one of the major reservoirs for this species in North Carolina.

Phase III will also entail the establishment of Advisory Committees, possibly one for endangered animals and another for endangered plants. These committees will consist of professional persons as well as representatives of landowner and other interests. Their function will be to advise the Wildlife Resources Commission in regard to official designation of endangered and threatened species and development of regulations governing human activities relating to them. They will also provide input for other management programs. There are probably several here today who could render valuable service in this manner.

The Wildlife Commission will need the active advice and support of many people and other agencies if it is to effectively meet the needs of endangered species. It currently enjoys a good working relationship with other Divisions within the Department of Natural and Economic Resources and cooperates actively with the Department of Agriculture and the N. C. State Museum as well as several Federal agencies. We need to broaden these working relationships and especially those with academic institutions, many of which are represented here today.

In conclusion, we would like to focus on three items that are urgently needed to assure the development of a strong and effective endangered species preservation program in North Carolina. We believe that those in attendance here can help attain these objectives and we actively solicit your support.

The first need is in regard to legislation. We need to amend the present wildlife law so as to fully clothe the Wildlife Commission with authority over the conservation of wild plants. This is necessary so that we can conduct a balanced program that relates to both groups of species that constitute our eco-systems.

The second need is to develop additional sources of funds to provide matching money for federal grants. At the present time, the primary source of funds available to the Wildlife Commission comes from the sale of hunting and fishing licenses. While hunters and fishermen are actively supporting endangered species conservation, excessive use of license money could constitute "diversion of funds" and raise questions in regard to proper handling of finances. The Commission will attempt to fulfill this need through sale of emblems and prints of paintings and will accept contributions to a special endangered species fund. We will be appreciative of your support in this funding effort. If you have any other ideas on how to raise the money please let us hear from you.

The third need for a successful endangered species preservation program is the development of effective communication between you the lay public and us the state agency. We are deeply appreciative of this opportunity to bring you up to date on what we have been doing in this important area. We need to continue this communication and we invite you to let us have the benefit of your thinking in the days and months ahead. We need your advice and guidance because you are the experts and we trust you will be generous with your input.

EXPLOITATION OF ENDANGERED PLANTS AND THEIR HABITATS

by

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ABSTRACT

Native plants have played an important role in the development of our nation. We no longer depend on native plants for their medicinal or food values to the extent that early Americans did. Some of our native plant species are decreasing in numbers because of various forms of exploitation. Examples are large-scale acreage conversion, commercial development, public projects, commercial collecting and private collecting. If State programs are to be effective in the protection and management of endangered species several program elements need immediate attention. Implementation of information, education, and enforcement program elements are essential. Program staff must also demonstrate to top management that rational and realistic management for endangered plants is possible.

INTRODUCTION

The exploitation of native plants has been a fact of life throughout history. There have been times when, except for native plants, human beings might have perished. There have been many volumns written on the subject of the use of native flora, and the significant part it has played in the development of our nation. American folklore contains numerous accounts of life-saving plants as well as notorious life-taking plants. Americans have a heritage deeply enriched by native plant life.

Unfortunately, our native flora does not, and never has existed in inexhaustible quantities. Many of our country's greatest naturalists began to warn us as much as a century ago that Americas' native plants and animals exist in finite numbers and special care would have to be taken in order to preserve them. Today in our technologically advanced society, we no longer find it necessary to exploit our native plants for the medicines and foods to insure our personal survival or the survival of our families. Why, then, do we continue to find that some of our native plants are decreasing in numbers at an alarming rate?

It is apparent that certain forms of exploitation continue to assure the demise of certain members of our native flora. It is also apparent that immediate action is needed if the state agencies of the southeast which are responsible for the protection and management of endangered plants, are to be effective in insuring the prolonged existence of this valuable part of our natural heritage.

Large-scale Land Use Influences

Large quantities of land which provide habitat for many of our endangered plants are being modified as a result of changing land use practices. For example, thousands of acres of hardwood timber are annually being converted to pine monoculture forest. In addition to the loss of the hardwoods this conversion represents the loss of untold acres of natural stands of understory vegetation, some of which are considered to be endangered.

Some farmland is now being taken out of production, but substantial portions of this are being planted with pine for commercial purposes. Nationwide, approximately 1.25 million acres of cropland is being taken out of crop production annually (Council on Environmental Quality, 1975). This is land which could once again be available as habitat for endangered plants if it were allowed to revert through succession to its natural climax state.

Some hardwood to pine conversion attempts have met with poor results. One example is the wind rowing and conversion of sandridge communities to pine. The result has been stunted tree growth and an otherwise relatively sterile vegetative community. Since this timber crop will return a marginal profit, if any, the planting of the sandridge with pine seems only to achieve the destruction of habitat where studies indicate endangered species may be concentrated (Smithsonian Report, 1975).

The idea fostered by timber interests that the forests of the southeast states should be used primarily as a source for pulp, has placed additional pressures on populations of endangered plants by reducing the overall age and maturity of our southeastern forests and underwritten the policy of converting hardwood stands to plantation pine stands. Companies who practice this unwritten policy use the beech and maple forests of the northeast and the spruce and fir forests of the Pacific Northwest for their source of saw timber.

Ironically, while land suitable for agriculture is being taken out of production in parts of the southeast, additional acres of habitat are being lost to crop production on lands heretofor not used for intensive agriculture. This trend is due in part to the increasing use of irrigation in the southeast. The increase in acreage being irrigated annually is not known, but it is thought to be substantial.

Increased pressure to develop coal reserves and other mineral resources of the southeast also accounts for increases

in loss of endangered plant habitat through strip mining operations.

Commercial Development

According to the Smithsonian Institute's report on Endangered and Threatened Plant Species of the U.S. (1975), endangered species are usually found in narrow niches, such as mountain tops, ravines, river banks, acid bogs or rock cliffs. It is certainly less than a coincidence that much of the second home development boom of the late sixties and early seventies occurred at or near these types of natural features. They are some of the most scenic, remote and unspoiled areas of the southeast region of the country. The destruction of many endangered plants of these areas went largely unnoticed by the developers, the builders, and the buyers partly for lack of interest, but possibly more for lack of knowledge as to alternatives. It is possible, for example, that a state endangered species technical assistance program could have provided information which would have minimized the destruction. Advice to remove the top soil from roadcuts and other construction sites and filling with it when construction was complete may have saved large amounts of organic substraits. Or the assistance might go so far as to suggest sales slogan such as "Rare Homes with Rare Plants" as a means of informing potential buyers of the unique features offered by this development.

In a similar manner, advice given to new home owners about the rare beauty and fragile nature of his plants and how he should care for them would very likely give rise to an attitude of personal stewardship for the entire community.

While this type of development is experiencing a temporary lull, there is evidence that residential development in relatively unspoiled areas continues. The Bureau of Census (1975) reports that since 1970, metropolitan areas have grown at a slower rate than non-metropolitan counties. And the indications are that instead of moving back to the farm, people are moving to within commuters reach of the smaller towns. This indicates that residential development associated with such a move will now be a primary residence - not a second home - built within one of the aforementioned narrow niches. Hence the exploitation of areas likely to harbor endangered plants continues. Other studies (Domestic Council, 1974) indicate "big increases" in the growth rate of the southern Appalachians, one geographic region which was identified by the Smithsonian Report (1975) as an area "with concentrations of endemic species" which may be endangered.

Public Projects

Many controversial statements have documented the exploitation

of fragile resources by public agencies such as the U.S. Corps of Engineers, U.S. Forest Service, and State and federal transportation and agriculture agencies. It is not difficult to find serious disagreement among different government agencies as to which one is actually conducting it's business in the public interest. Admittedly, usually both are, each using its' own criteria for measuring achievement. The simple fact is, that vast acreages of land - some harboring endangered species - have been and are being consumed by public projects throughout the southeast. According to 1973 figures, the U.S. Corps of Engineers had under management, more than 470,000 acres of flat water in its South Atlantic Division alone. Of course, the acreage of habitat consumed by creating that flat water would be considerably greater. Since those figures were released at least two additional major reservoirs have been created in Georgia (i.e., West Point Reservoir and Carter Reservoir), both of which inundated habitat which harbored endangered plants. This is especially true of Carter Reservoir which flooded approximately 8000 acres of habitat along the banks of the Coosawattee River in north Georgia.

The Georgia Statistical Abstract (1968, 1972) published by the State Highway Department indicated that more than 10,200 miles of public roads were constructed from July 1, 1968 to May 12, 1972. More recently proposed roadways include the Appalachian 400 Highway which will slice through thousands of acres of prime north Georgia habitat. With habitat being lost at such alarming rates, it is little wonder that the International Union for Conservation of Nature and Natural Resources (1974) projects the extinction of an additional 185 species by the year 2000.

EXPLOITATION FOR PROFIT AND FOR LOVE

Commercial Collecting

The collecting of native plants for sale has been an occupation for some of our people for generations. For others, it is a relatively new business. In either case, this type of exploitation consists of the collecting and transporting of plant materials for the expressed purpose of resale. Commercial collecting operations range in magnitude from one person attempting to scratch out a meager income for himself and his family, to several teams of well-equipped collectors who can easily carry away enough material in a day to turn a handsome profit.

The effects of the commercial collector can be equally as devasting as the bulldozer and earthmover. Entire populations of Golden Seal (*Hydrastis canadensis* L.), Moccasin Flower (*Cypripedium acuale* Ait.),and Pitcher-plants (*Sarracenia* sp. L.) have disappeared over night as a result of commercial collecting operations. There

is little question that exploitation of endangered plants by commercial collectors can have a significant negative influence on the continued existence of the species.

Private Collecting

Various interests in our native plants by the public have led to the unquestionable exploitations of the very object of the interest. Accounts of my own life serve well to illustrate this exploitation by private citizens. As a small child, I remember helping - in my own way - my family dig Genseng (*Panax quinquefolium* L.) and Golden Seal (*H. canadensis* L.) near my Ellijay, Georgia home. As a boy growing up on the banks of the Coosawattee River, I was proud to bring home a handfull of Yellow-Lady Slippers (*C. calceolus* L.) to my mother. As a student of botany, I was taught that rare plants should not be collected except in the interest of science, but collections have been made to trade to other herbaria. And just a few weeks ago a friend came to my house and because he knew how much I studied and admired wildflowers, he brought me a whole bucket full of Large-flowered Trillium (*Trillium grandiflorum* (Michx.) Salisb.) Finally, accounts were described to me recently of a wildflower club field trip to a very small colony of Golden Seal (*H. canadensis* L.); several days later the entire colony had disappeared.

The point of these ramblings is that regardless of whether a species is used to death for medicinal purposes, studied to death in the interest of science, or loved to death because of its' spectacular beauty, the result is the same: the methodical and unnecessary destruction of part of our natural heritage.

PERSPECTIVE OF THE STATE

Mandate for Action

All of the means of exploitation which have previously been discussed with the exception of private collecting have one grave consequence in common. Tremendous numbers of acres of habitat for endangered plants are being lost. Another glaring problem is that there is no universal sense of values in and no universal policy for management of endangered species which exist among environmental groups, private industry, federal and state government agencies, or the scientific community.

It is not always apparent that state agencies have a clear-cut mandate to protect endangered species and their habitats considering the wide spread habitat destruction which continues to occur throughout the southeast. In fact there is seldom a responsibility given by legislation to a state agency which does not in

some way conflict with responsibilities previously deligated to other state agencies.

The mandate to manage and protect endangered species does exist in Georgia in the form of two state laws (The Endangered Wildlife Act of 1973 and The Wild Flower Preservation Act of 1973). And as we would expect, several of Georgia's state agencies have received mandated responsibilities which seem to be in conflict - at least philosophically - with the concepts of endangered species management and protection. The ultimate success of the endangered species program and other programs which face conflicting agency philosophies will depend largely on the cooperative attitudes of all agencies involved in working together openly to resolve points of conflict.

Immediate Needs for Program Development

Endangered species programs of many of the southeastern states have from their beginnings been low budget operations. In Georgia, less than $30,000 annually has been invested except for substantial expenditures by the Georgia Heritage Trust Program for habitat acquisition.

Much of the information which has been compiled to date relating to endangered species in Georgia is the result of a very small program staff working with an army of concerned citizens and other volunteers. While considerable information does exist, it is usually not organized in such a manner as to be either readily useful or even available to persons or agencies who inquire after it. Consequently, little organized information has reached a point where it can be used in the struggle to curtail further destruction of endangered species and their habitats.

First, the state program must be funded at levels where it can perform its duties full-time. In general, state programs receive financial support when they have a broad base of moral support. Therefore, one of the primary objectives of any states' program should be to take steps to broaden its base of support. The most efficient way to do this may be through the development of a strong educational program and an efficient method of distributing information.

There is a critical need for the development of the strongest technical assistance program possible. Every single piece of information which exists related to the states' endangered species should be compiled and organized in a form which will allow the program staff to furnish data upon request to user organizations such as local or county planners and other state and federal agencies. This may be the best means of reducing destruction of endangered

species habitat on a large scale, since it will allow these agencies to react to environmentally sensitive areas during early planning stages.

Finally, one of the most urgent needs to assure sound program development is the implementation of an effective and realistic law enforcement effort. In Georgia, as I am sure is the case in other states, our law enforcement personnel are among our most avid conservationists. Even among these people who normally have a high level of interest, there are legitimate concerns which have been voiced involving law enforcement activities related to endangered plants. The most common objection is that law enforcement personnel would never be able to recognize endangered plants. Certainly this is a problem, but it is a problem with solutions.

The solution might take the form of one of several alternatives. First, and most ideally, in-service training programs can be designed which will teach law enforcement officers how to recognize and identify endangered species of plants. This may be too idealistic if short term implementation is the goal. In Georgia there are 100 species of endangered plants now protected by law.

An alternative may be to select targets (species) of concentration and teach enforcement officers how to recognize these specific ones. The species selected would be based upon previous evidence of exploitation. This enforcement effort would require that enforcement personnel be able to recognize 4 or 5 (possibly as many as 10) species of plants. This is not an unmanageable or unrealistic goal.

A last alternative may be to concentrate our enforcement effort on inspections of commercial operators who deal in native flora. This inspection responsibility could be assigned to qualified botanists or to other personnel who have the training and expertise required to recognize and identify the species in question.

Conclusion

The passage of legislation which calls for strong protective measures and management programs for endangered species is legitimate cause for celebration. It does not, however, mean that a solution to the problem has been attained. The true test of the effectiveness of any particular piece of legislation can only be measured after the full implementation of the programs which it authorized. The judgement of the effectiveness of State endangered species programs as well as the federal endangered species program is incomplete. A great deal of program implementation remains ahead. In this regard, two items stand out as absolute necessities to the development of a State program which will achieve the goals of endangered species legislation.

First, existing information from all sources (i.e. scientific community, private, state and federal agencies) must be organized and distributed to a level where it can have an influence on the preservation of habitat. Planning agencies can not possibly construct plans in harmony with endangered species habitat if the location of that habitat is not known and the conditions to which endangered species are sensitive are not known.

Second, State endangered species programs must prove themselves to be manageable. In many instances internal management conflict is the reason for the slow development of the program. Executive management has been bored with philosophical rhetoric and the operative staff has been confused and bewildered by such things as lists (in Georgia) of over 600 species of the most infrequently encountered species of plants and animals in the state which are suspected of being endangered. Both groups must be convinced that rational and realistic - though it may not be conventional - management is possible.

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VENUS' FLYTRAP: SURVIVAL THREATS AND POTENTIALS

Raymond O. Flagg[1/]

Abstract.--Road construction and pine farming have increased the available sites for natural stands of Venus' flytrap, but drainage projects and intense collecting in recent years have destroyed many populations and severely reduced others. While the flytrap does not seem to be in immediate danger of extinction, it might well be considered unnecessarily threatened, as commercial propagation appears to be practical.

Additional keywords: Dionaea muscipula, habitat.

In 13 years of observing, collecting, and growing Venus' flytraps (*Dionaea muscipula* Ellis), I have seen old populations disappear, new populations become established, and advances in culture methods.

HABITAT

The Venus' flytrap is endemic to eastern North and South Carolina. It grows in sandy, humus, acid soil, usually in the company of pines and short compact sphagnum. Flytrap populations thrive in full sun and partial shade, and will tolerate moderately heavy shade. In full sun, partial shading is usually provided in the summer by grasses and small herbs. The suitability of a particular spot appears to be determined by available moisture--populations survive short periods of drying or flooding, but generally a moderate amount of ground moisture is present year-round.

Destruction

The most destructive activity of man to flytrap habitats is the drainage accompanying building projects, road construction, agriculture, and silviculture. A permanent significant drop in the water level spells the end of the flytrap population at a specific site.

Populations of flytraps also tend to die out as pine fields mature. I do not know whether this is because of increased shading, heavy littering by needles, or a combination of these changes.

Development

Although the flytrap is restricted in habitat, it is in many respects a "campfollower" species. Most of the places where it grows can be called disturbed areas: roadsides, edges of shallow borrow pits, new pine plantings, ditches around and through older pine plantings, and areas where pine plantings meet ponds or swamps. Thus, man destroys old habitats by drainage and creates new ones by disturbing land levels. Furthermore, controlled burning in pine plantings favors the flytraps. Even though the number of flytraps has been sharply reduced by collecting in the last decade, I wonder if there are not more flytraps now than there were in the days of Sir Walter Raleigh.

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COLLECTING

By North Carolina law anyone may take up any plant on his own land or on any private land with signed authorization of the owner or the duly authorized agent.

Carolina Biological Supply Company

By state permit we may collect up to 500 Venus' flytraps each year. We tend to use the same collecting sites year after year, and make it a point to operate within the laws of man and of conservation.

One of the reasons I enjoy my association with Carolina Biological rests in the judicious husbandry of collecting sites by the conservation-conscious staff. It has been my pleasure to be involved in collecting plants For Carolina Biological for 13 years. In all that time I have never seen a population threatened or endangered by the activities of any employee of the Company. Even if the collecting habits of Carolina Biological did not rest in pure biological appreciation of nature, maintenance of productive sites would appear to be simple wisdom for long-term utilization--over-collecting this year would create supply problems next year.

"Dime-Store" Trade

Carnivorous plants have novelty and beauty that appeal not only to biologists but also to almost any human being. Collecting activity to fill the layman's demand has placed extreme pressure on many carnivorous plants, especially the Venus' flytrap.

There are individuals who place no value on collecting sites and violate all rules of conservation. I have personally seen evidence of destructive and illegal collections at many locations on state property along highways in Brunswick and Pender Counties in North Carolina. Many flytrap populations along the roadsides in these counties have been completely removed in wanton digging by insensitive, if not biologically ignorant, individuals. Any plant-lover viewing the before and after conditions of such ravished sites is struck with sadness and anger. Some portions of the gene pool of the flytrap have undoubtedly been lost forever. If the laws of North Carolina were enforced along the roadsides, there would be no threat to "shut-your-mouth Sam."

PROPAGATION

Natural Sites

Venus' flytraps have survived in the New Jersey Pine Barrens since 1948 (Smith, 1972). In recent years we have successfully translocated flytraps within the natural range, and now use the locations as collecting sites. For example, ten or eleven years ago we took a number of flytraps from our Burlington greenhouse and planted them in Bladen County about 3.5 miles NE of White Oak along a roadside ditch draining into Singletary Creek. (We are not aware of any native sites of Venus' flytraps within a 20-mile radius.) Although the potential niche was small, the few original plants proliferated and the offspring even survived through a minor shift in the niche induced by reworking of the drainage area by the Department of Transportation. Almost annually we collect 75 to 100 flytraps from this little site without diminishing the basic size of the colony. Only large plants are taken; small plants and seedlings are left in place. The size of the colony is restricted by the immediate environment,

most importantly by the availability of water.

Some large suppliers of flytrap "bulbs" indicate they are meeting their needs from plants grown on their own property. While this may be true, I must view it with some doubt as it still appears more economical to purchase "bulbs" from local collectors than to propagate them. Of course, the very cheapness of "bulbs" in large quantities would indicate that flytraps are not difficult to find, and thus not rare.

Greenhouse

Reputedly, flytrap seed have brief viability (a few months) and seedlings have difficulty in becoming established (Smith, 1972). This may be true with poorly handled seed, but it has been our experience that properly dried and refrigerated seed consistently show good germination and good seedling establishment two years after harvest. With high humidity, elevated temperature, and natural greenhouse light, we have produced flytraps with attractive multi-leaved rosettes (about 5-7 cm in diameter) in less than a year after sowing the seed.

We have produced flytrap seed in the greenhouse, but cross-pollination by hand was necessary.

Hooft (1974) summarized our experience with vegetative propagation of flytraps. When excised healthy petioles with the traps removed are kept in a moist, warm and light environment, small buds form in about a month, complete leaves with traps form in about two months, and roots are produced as decomposition of the original petioles becomes well advanced. With high humidity, elevated temperature, and natural greenhouse light, many of these plantlets develop into fine specimens.

CONCLUSIONS

Although Venus' flytraps have been subjected to increased pressures in recent years, the species does not appear to be in immediate danger of extinction, as its continuation is encouraged by extensive pine farming within its natural range. The ready availability of collected "bulbs" indicates that there are many wild flytraps; however, many populations have been decimated and the range and activities of collectors are increasing. Aside from collecting wild flytraps, it is now practical to produce these plants from seed and from vegetative propagation.

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THE NATURAL LANDMARKS PROGRAM

Gary S. Waggoner1/

Abstract,--The National Park Service administers two programs to preserve nationally significant natural areas, the National Park System and the Natural Landmarks Program. The Natural Landmarks Program is a recognition program to encourage the voluntary preservation of significant natural areas on non-Park Service administered lands. Natural region studies and onsite evaluation studies are conducted by scientists under contract to the Service. Sites determined to be nationally significant are entered on the National Registry of Natural Landmarks by the Secretary of the Interior.

The protection of endangered plant species through natural area preservation is approached in two different ways by the National Park Service. Most people are aware of the preservation efforts of the Service as reflected in the National Park System, especially the great natural area parks such as Great Smoky Mountains National Park and Everglades National Park in the southeastern United States. These parks are publicly owned and are administered by the Service. Thus, there is the highest possible degree of protection afforded to endangered or threatened species indigenous to such parks. The Service can control visitor use and access to such habitats, including closure to entry for other than official purposes. The purpose of this paper, however, is to describe the Natural Landmarks Program, a method of encouraging the preservation of natural areas outside the National Park System.

The Natural Landmarks Program, which was administratively created by the Secretary of the Interior in 1962, is managed by the National Park Service pursuant to authority contained in the Historic Sites Act of 1935. The objectives of the Natural Landmarks Program are: 1) to encourage the preservation of sites illustrating the geological and ecological character of the United States, 2) to enhance the educational and scientific value of sites thus preserved, 3) to strengthen cultural appreciation of natural history, and 4) to foster a greater concern in the conservation of the Nation's natural heritage. Under this program the Service strives to assure the preservation of such a variety of nationally significant natural areas that, when considered together, they will illustrate the diversity of the country's natural environment.

In contrast to the actual units in the National Park System, natural landmarks are nationally significant natural areas which are in varying ownership, e.g., private, State, Federal. The Natural Landmarks Program is a voluntary, recognition program and neither ownership nor responsibility for the area changes with designation. Instead, following designation of a

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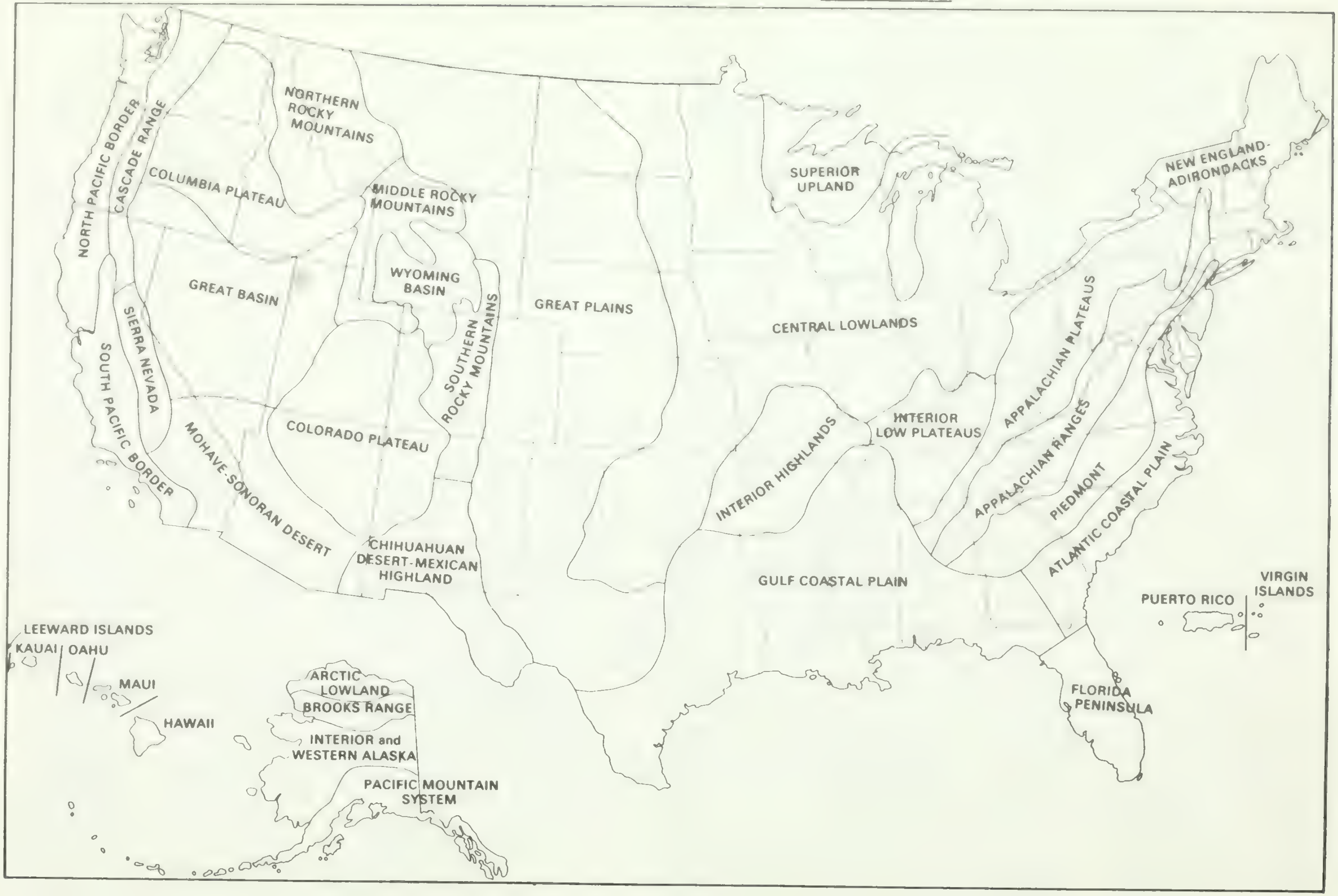
landmark by the Secretary of the Interior, the owner(s) is notified that his property has been determined to be of national significance as a superlative example of our natural heritage and he is invited to voluntarily register the property. This registration act is a gentleman's agreement made between the owner(s) of the landmark and the Secretary of the Interior stipulating that the owner(s) intends to preserve the site in such a way as to maintain its inherent natural integrity. This registration act is not legally binding and, therefore, long-term preservation of a registered natural landmark is not as certain as in a unit of the National Park System.

Natural landmarks are determined as a result of a fairly thorough selection process. The National Park Service is presently conducting studies, typically through contracts with universities, of the various natural regions of the United States. In the Southeast, these natural regions include the Atlantic Coastal Plain, the Gulf Coastal Plain, the Florida Peninsula, the Piedmont, the Appalachian Ranges, the Appalachian Plateaus and the Interior Low Plateaus (Map 1). Natural region studies describe and classify the important ecosystem types or community types occurring within a particular region and then provide an inventory of natural areas which significantly illustrate each ecosytem type previously described. Sites are assigned a priority by the natural region study team based on a comparative analysis of similar sites. Important factors considered in this comparative study include the presence of endangered or threatened biota, the naturalness or integrity of the site, the ecological diversity of the site, the rarity or threat to the ecosystem type, the relictual or distributional significance of the site and other similar factors. In addition, each natural region study contains similar information on important geological areas. However, this paper emphasizes the ecological portion of the Natural Landmarks Program.

A second phase of study involves the onsite evaluation of sites highly recommended in the natural region study. This onsite evaluation is also conducted via contract to a competent scientist in the vicinity of the areas to be evaluated. Emphasis in contracting both the natural region studies and the onsite evaluations of ecological sites is usually given to botanists, especially plant ecologists. The onsite evaluation provides more detailed information on each site, a recommended boundary, and a significance statement which briefly states why the site is considered to be of national significance. In most instances, the onsite evaluation studies are conducted by a different scientist thus providing a "second opinion" as to the relative ecological significance of the site.

Once both of these steps are completed, the Natural Landmarks Program staff reviews and verifies the information available, makes additional contacts with other scientists and finally makes a determination as to whether or not the area appears to qualify as a natural landmark. The primary test is one of national significance. National significance is ascribed to those superlative areas which are true, accurate and essentially unspoiled examples of our natural heritage. The Natural Landmarks Program staff presents the best areas to the Secretary of the Interior's Advisory Board on National Parks, Historic Sites, Buildings and Monuments which meets biannually in Washington, D.C. The Advisory Board then makes recommendations to the Secretary with whom rests the ultimate authority for the establishment of natural landmarks.

Map 1. Natural Regions of the U.S.*



* Based on Fenneman's (1928) Physiographic Divisions of the United States.

The National Registry of Natural Landmarks is the official listing of all natural landmarks and is published periodically in the Federal Register. At present, there are 421 established natural landmarks with 61 occurring in the Southeast. Of these 61, 18 have been established as natural landmarks for their geological significance, the remaining 43 are nationally significant ecological areas.

Designation as a natural landmark provides protection primarily as a result of the National Environmental Policy Act of 1969. This Act provides that for all federally financed or licensed activities which have a significant effect on the environment, an environmental impact statement must be written considering, among other things, the occurrence of nationally significant natural areas in the selection of alternatives and mitigating actions. Several States across the Nation have comparable laws regarding State-funded or licensed projects. The principal protection provided by natural landmark designation, therefore, is to call attention to areas containing exceptional natural values so that intelligent planning and land use decisions can be facilitated and if significant natural resources are potentially affected, mitigating actions can be taken to minimize the environmental impact. Numerous situations have occurred where proposed plans have been significantly altered and even abandoned due, at least in part, to the presence of natural landmarks at proposed project sites.

Formal agreements between the National Park Service and the U.S. Forest Service, U.S. Fish and Wildlife Service, and the Bureau of Land Management concerning the designation of natural landmarks on these public lands have created a more permanent form of preservation for these sites. Information on registered natural landmarks is provided to each administering agency so that the information can be incorporated into the management plans for the appropriate public land units. Such plans form the basis for the type of management permitted. Natural landmark designation requires that the integrity of the natural area be maintained; however, the specific type of use permitted is left up to the particular bureau administering the property. In other words, various types of use may be permitted as long as the significant natural values of the site are not impaired. Such compatible uses might include nondestructive scientific use, interpretation for the public, fishing, nature study, photography, hiking and other basically nonconsumptive uses.

Registered natural landmarks have also been established on other federal lands including those administered by the U.S. Air Force, U.S. Navy, U.S. Marines, U.S. Army, The Energy Research and Development Administration, Bureau of Reclamation, Bureau of Indian Affairs and the U.S. Coast Guard. In most instances, the landmark designation brought the special significance of these particular sites to the attention of decisionmakers. The registration of these sites by the respective owners has helped to insure the preservation of several significant natural areas. Registration of natural landmarks on State-owned lands has also helped to insure the long-term protection of significant areas. In some instances, registered natural landmark status merely provides another "layer of protection" to an already recognized natural area but it does reflect perhaps the highest level of importance, that of national significance. In many instances, however, designation as a natural landmark provides the initial, official recognition of important natural areas. This is especially true with sites in private ownership.

While no absolute legal protection is afforded registered natural landmarks, the recognition factor has proven to be quite effective as a means of preservation. The National Park Service is continuously providing information concerning the locations of significant natural areas, regardless of ownership, to those public and even some private organizations responsible for planning developments. This information is received in a very appreciative manner and is relied on heavily in the planning phases of development thus avoiding the needless destruction of known important natural resources. At the present time, the Natural Landmarks Program staff knows of only two instances where natural landmarks have been impacted to the point of losing their inherent natural integrity. Further, Land and Water Conservation Fund monies have been used in several instances by States to acquire natural landmarks for State Natural Areas or other preservation land use categories. The Nature Conservancy, a private, non-profit, natural area preservation organization, also has information on existing natural landmarks as well as potential natural landmarks (sites under study) to assist them in setting priorities for their natural area acquisition efforts. The record shows that the Natural Landmarks Program has been effective in its efforts to encourage the preservation of nationally significant natural areas through the process of recognition on both public and private lands.

The establishment of natural landmarks depends heavily upon the information provided by scientists. The locations of endangered and threatened flora and fauna, the occurrences of disjunct and relict plant communities, the site of outstanding representative examples of regionally typical ecosystem types, and other similar information are all essential to the efficient functioning of the Natural Landmarks Program in its efforts to recognize nationally significant natural areas. Such information can only best be provided by scientists. The Natural Landmarks Program staff is fully aware of the sensitivity of certain types of information including the precise locations of endangered and threatened species, the locations of significant fossil deposits, the occurrences of outstanding, noncommercial caves, and the like. Such information is treated with great care. Advice on the possible limited dispersal of this information is obtained from scientists knowledgeable of the area and the potential threats to the site's continuing integrity. It is vitally important that information on outstanding natural areas including areas harboring endangered or threatened species be made available so that development does not unknowingly destroy unique areas needlessly. The efforts of the National Park Service in this regard are helping to avoid land use plans being made in ignorance of significant ecological information.

Presently, both the Piedmont and the Atlantic Coastal Plain natural region studies involving ecological sites are completed. Two others, the Gulf Coastal Plain and the Appalachian Plateaus natural region studies are scheduled to be completed this summer. The Interior Low Plateaus study has recently been contracted with Dr. Elsie Quarterman, Biology Department, Vanderbilt University, Nashville, Tennessee, but the remaining two natural region studies involving the Southeast have not yet been contracted. If you would like to contribute information regarding a significant natural area, please contact the Chief, Division of Natural Landmarks, National Park Service, Department of the Interior, Washington, D.C. 20240.

ROLE OF FISH AND WILDLIFE SERVICE CONCERNING ENDANGERED FLORA

Vernon G. Henry[1]/

Abstract.--As the principal agency of the Federal Government with responsibilities for conserving wildlife resources, the Fish and Wildlife Service has had an impact on the flora of this nation. Overall 34 million acres nationally and 1-3/4 million acres in the southeast are managed by the Service as part of their refuge system. All eight major North American biomes are represented by refuge lands and nearly all species of aquatic plants common to North America are found on the 12.5 million acres of wetlands of the refuge system. These lands include 191 natural areas, 43 wilderness areas and 65 special sites preserved for ecological, scientific or cultural values. In the southeast 372,644 acres are in National Historic Landmarks, 41,892 acres are in research natural areas and 418,024 acres are in wilderness areas. Numerous endangered and threatened plants are found on these lands and are protected. Through grant-in-aid programs, states have purchased over 3-1/4 million acres and manage an additional 51 million acres by lease or licensing agreement. These areas have also played a role in conservation of plants. With the passage of the Endangered Species Act of 1973, the Fish and Wildlife Service's role has expanded. The Service is now responsible for listing and delisting, enforcement of prohibited acts, utilizing other programs in furtherance of the purposes of the Act and consulting with all other federal agencies concerning their programs.

INTRODUCTION

The Fish and Wildlife Service has assumed a more prominent role recently in preserving, maintaining and managing endangered flora as a result of the Endangered Species Act of 1973. This same statement is true to a lesser degree of all land resource management agencies at the federal level and potentially even at the state level. However, to assume that passage of this legislation initiated the Service's involvement with endangered flora would be erroneous. I would like to explore the past, present and future role of the Service concerning flora in general and endangered flora in particular.

The Service is the principal agency through which the Federal Government carries out its responsibilities for conserving the wildlife resources of this nation. One can not conserve wildlife without having a corresponding effect on the flora because the basic ingredient in wildlife management is habitat, which includes all the organic and inorganic elements present. A standard cliche used in wildlife management is that one does not manage wildlife but one manages the habitat. This is somewhat of an oversimplification but the emphasis is well placed. To carry it one step further, management of the habitat normally means management of the vegetation because

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many of the other elements are difficult at best to manipulate. A perusal of the curriculum of any school of wildlife management would show a strong foundation in botany.

NATIONAL WILDLIFE REFUGE SYSTEM

One of the major ways in which the Service impacts the flora of this nation is by management of lands under the Service's control. As of June 30, 1975, the lands in the Service's Refuge System totaled 34,136,463 acres in 563 units (U. S. Fish and Wildlife Service 1975a). The Refuge System includes waterfowl refuges, waterfowl production areas, general migratory bird refuges, game ranges, big game refuges, wildlife ranges and coordination areas. These refuges range in size from 0.6 acre to 8.9 million acres (U. S. Fish and Wildlife Service 1976).

In the southeastern region [2] there are 1,781,626 acres involved in 89 units (U. S. Fish and Wildlife Service 1976).

Vegetation found within the Refuge System includes species common to all eight major North American life zones, or biomes. In the southeast four biomes are involved, i.e., tropical forest, deciduous forest, coniferous forest and grassland. Manipulation of vegetation for wildlife management purposes occurs primarily in three biomes, all of which are present in the southeast, i.e., deciduous forest, coniferous forest, and grassland. These three biomes comprise 23 percent of the total system-wide acreage and 80 percent of all refuges are found in these three biomes.

Although national refuges protect many types of wildlife, they play an especially important role in management of waterfowl, and thus, in management of aquatic flora. Nearly all species of aquatic plants common to North America are found on the 12.5 million acres of wetlands encompassed by the Refuge System (U. S. Fish and Wildlife Service 1976).

The acquisition, leasing and acquiring of easements of lands for the Refuge System has, in many cases, prevented the imminent destruction or conversion to non-native habitat of the lands involved (Bureau of Sport Fisheries and Wildlife 1975).

Overall, the major effect on vegetation is to provide a diversity, both in vegetative types and successional stages (U. S. Fish and Wildlife Service 1976).

Natural type areas

All refuge lands are not intensively managed; some are retained perpetually in their natural state for several reasons including inaccessibility, need to protect endangered species, legal restrictions or to maintain naturalness. Wilderness areas, scientific sites and natural areas are examples of areas preserved in a natural condition (U. S. Fish and Wildlife

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2/ Includes: Florida, Georgia, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, Kentucky, North Carolina, South Carolina, Puerto Rico, and Virgin Islands.

Service 1976).

As unique habitats are destroyed throughout the Nation, those within refuges take on greater importance and will receive increased protection to maintain their integrity. Refuge personnel will continue to analyze the need for additional sites for inclusion in these special protection areas (U. S. Fish and Wildlife Service 1976).

At the present time there are 191 natural areas, 43 wilderness areas and 65 special sites preserved and protected for their ecological, scientific and cultural values (U. S. Fish and Wildlife Service 1976). All of these type areas can and do play a role in preserving endangered plants.

The first objective in the recently prepared Environmental Statement prepared on Operation of the National Wildlife Refuge System was as follows: to preserve, restore and enhance in their natural ecosystems all species of animals and plants that are endangered or threatened with becoming endangered on lands of the National Wildlife Refuge System. An annual goal of 142 million use days for threatened and endangered species was set, some of which is for plants (U. S. Fish and Wildlife Service 1976).

In the southeast, Pelican Island is a National Historic Landmark and five areas totaling 372,644 acres are listed as National Natural Landmarks. These are Wassaw Island (10,760 acres)--Wassaw National Wildlife Refuge in Georgia; Beaver Dam Creek Swamp (530 acres)--Wheeler National Wildlife Refuge in Alabama; Big Lake Natural Area (6400 acres)--Big Lake National Wildlife Refuge in Arkansas; Okefenokee Swamp (353,981 acres)--Okefenokee National Wildlife Refuge in Georgia; and White River Sugarberry Natural Area (973 acres)--White River National Wildlife Refuge in Arkansas (U. S. Fish and Wildlife Service 1976).

Research Natural Areas found on refuges in the southeast total 41,892 acres in 31 units on 16 separate refuges (Table 1). These areas involve vegetative types as varied as sphagnum bogs, cordgrass prairie, swamps, marshes, deciduous woody cover, coniferous woody cover and hardwood-pine mixtures. There are also 18 Public Use Natural Areas on nine different refuges in the southeast which total 4514 acres (Table 2).

Wilderness areas totaling 557,670 acres have been designated on refuges nationally and 418,024 acres of these are in the southeast in eleven areas (Table 3). In addition, 7,493,132 acres are proposed in Congress and 13,608,826 additional acres are in some stages of review. The proposals include 13 areas in the southeast totaling 37,701 acres (U. S. Fish and Wildlife Service 1976).

Endangered Plants on refuge lands

With this general background, I wish to now present some specific examples, starting at the southern extremities of this region.

Encyclia boothiana, an epiphytic orchid only known to exist in a few relict populations in mangrove swamps in the Everglades and on the southwest Florida coast may occur in the Key Deer and Great White Heron National Wildlife Refuges.

Table 1 - Natural Areas Found on Southeastern National Wildlife Refuges

Refuge or Range	Natural Area	Primary Type	Acres
Big Lake	Big Lake Baldcypress	Baldcypress	500
Blackbeard	Blackbeard Island	Slash Pine-Hardwood	450
Cape Romain	Bulls Island	Sand Live Oak-Cabbage Palmetto	500
Cape Romain	Bulls Island	Loblolly Pine-Hardwood	500
Cape Romain	Bulls Island	Southern Red Cedar	80
Carolina Sandhills	---	Longleaf Pine-Scrub Oak	554
Holly Bend	Hog Thief	Cottonwood	100
Lake Woodruff	Honey Creek	Southern Cordgrass Prairie-Water Hickory-Carolina Ash-Bald Cypress-Red Maple	1,140
Mattamuskeet	Sayler's Ridge	Loblolly Pine	75
Noxubee	Morgan Hill	Red Cedar-Pine-Hardwood	67
Noxubee	Bluff Lake	Loblolly Pine	80
Noxubee	Old Robinson Road	Bald Cypress	46
Okefenokee	Black Jack Island	Sphagnum Bog Lake Swamp and Marshy Area Swamp Island	15,027
Okefenokee	Cowhouse Island	Live Oak	10
Okefenokee	Floyd's Island	Southern Scrub Oak	160

Table 1 (Cont'd)

Refuge or Range	Natural Area	Primary Type	Acres
Okefenokee	Sweet Bay	Sweetbay-Swamp Tupelo-Red Maple	2,560
Okefenokee	Pine Island	Pond Area	90
Okefenokee	Territory Prairie	Swamps & Marshy Area	1,450
Okefenokee	Pondcypress	Pondcypress	14,989
Piedmont	Five Points	Loblolly Pine-Shortleaf Pine	118
Sabine	Blue Islands	Sweet Gum Cordgrass Prairie	112
St. Marks	Otter Lake	Longleaf Pine-Scrub Oak	93
St. Marks	St. Marks	Slash Pine	203
St. Marks	St. Marks	Cabbage Palmetto-Slash Pine	24
St. Marks	St. Marks	Tidal Salt Marshes	828
Tennessee	Britton Ford	Eastern Red Cedar-Hardwood-Post Oak Black Oak-White Oak-Red Oak-Hickory Sassafras-Persimmon	750
Wheeler	Bluff City	Eastern Red Cedar	13
White River	White River Sweetgum	Sweetgum-Nuttall Oak Willow Oak	410
		Sugarberry-American Elm-Green Ash	109
		Overcup Oak-Water Hickory	454
Yazoo	Swan Lake Black Willow	Black Willow	400
Total			41,892

Table 2 - Public Use Natural Areas
Of The Southeastern National Wildlife Refuges

Refuge or Range	Natural Area	Primary Type	Acres
Cape Romain	No name #1	Estuarine salt-marsh	200
Chassahowitzka	Battle Creek	Estuary salt-marsh	40
J. N. "Ding" Darling	Gasparilla's Hideaway	Tropical flora and fauna	120
J. N. "Ding" Darling	Interpretive Trail	Estuaries-marshes-mangrove	85
Loxahatchee	Loxahatchee Slough	Wetland-Everglades	640
Loxahatchee	No name #1	Pond cypress	40
National Key Deer	Watson Hammock	Tropical Hammock	100
Okefenokee	Chesser Island Bay	Bog Wooded Bay	100
Okefenokee	Chesser Island Hammock	Hardwood Hammock	11
Okefenokee	Chesser Prairie	Marsh Prairie	800
Okefenokee	Chesser Prairie Rookery	Bird Rookery	3
Okefenokee	Floyd's Island	Special Island ecosystem	575
Santee	Dingle Pond	Aquatic ecosystem	615
Wheeler	Beaver Dam Creek	Tupelo Swamp	578
Wheeler	Dancy Bottoms	Mixed hardwood and Pine	186
Wheeler	Penny Bottoms	White Oak-Hickory-Red Oak	191
Wheeler	Village Creek	Red Cedar-mixed hardwood and Pine	105
Lake Woodruff	No name	Hardwood Hammock	125
Total			4,514

Table 3 - Wilderness Areas of the Southeastern National Wildlife Refuges System

Wilderness Area (Refuge)	State	Refuge Acres	Wilderness Acres
Designated			
Cedar Keys	Florida	378	375
Florida Keys	Florida		4,740
Key West	Florida	2,019	
National Key Deer	Florida	7,331	
Great White Heron	Florida	1,996	
Island Bay	Florida	20	20
Passage Key	Florida	36	36
Pelican Island	Florida	684	6
St. Marks	Florida	95,000	17,740
Blackbeard	Georgia	5,617	3,000
Okefenokee	Georgia-Fla.	371,445	353,981
Wolf Island	Georgia	5,126	5,126
Breton	Louisiana	5,047	5,000
Cape Romain	South Carolina	34,196	28,000
Totals-Designated Areas		528,895	418,024
Proposed			
Big Lake	Arkansas	10,974	1,818
White River	Arkansas	112,399	975
Chassahowitzka	Florida	29,698	16,900
J. N. "Ding" Darling	Florida	4,307	2,735
Lake Woodruff	Florida	18,417	1,106
Savannah	Georgia-S. C.	13,173	Nonsuitable

Table 3 (Cont'd)

Wilderness Area (Refuge)	State	Refuge Acres	Wilderness Acres
Lacassine	Louisiana	31,776	2,854
Noxubee	Mississippi	45,763	1,200
Cedar Island	North Carolina	12,526	180
Mattamuskett	North Carolina	50,179	590
Pea Island	North Carolina	5,915	180
Swanquarter	North Carolina	15,500	9,000
Santee	South Carolina	74,353	163
Total: Proposed Areas		424,980	37,701

This species is listed in the Smithsonian Institution Report as threatened and is listed as endangered by the Florida Committee on Rare and Endangered Plants and Animals. Although not all are listed on known lists of endangered plants, most of the epiphytic orchids in the United States are threatened to some extent by land clearing and development coupled with drainage for agriculture and residential areas.

Cactus Hammock, located in the southeastern-most portion of Big Pine Key, is being considered for inclusion into the Great White Heron Refuge. This area contains several endangered or threatened plant species including the following cacti: Cereus robinii, Cereus gracilis var. simpsonii, Cereus eriophorus var. fragrans, Opuntia triacantha and Opuntia cubensis. The first three are listed as endangered and the fourth as threatened in the Smithsonian Report. Cereus robinii is also listed as endangered by the Florida Committee on Endangered Plants and Animals and this same group listed prickly apples (Cereus gracilis var. simpsonii) as threatened. One variety of the tree cactus, C. robinii, occurs nowhere else in the world. The prickly pear (Opuntia cubensis) is not found on known lists of endangered flora but, like C. robinii, is found nowhere else in the world and should probably be listed. Wild Cotton (Gossypium hirsutum), listed as endangered by the Florida Committee, is also found in Cactus Hammock.

Moving up the coast, Loxahatchee National Wildlife Refuge harbors at least two species in trouble. One is the Ray fern (Schizaea germanii), a rare fern thought not to occur outside of the Everglades, is listed as endangered by the Smithsonian Report and as rare by the Florida Committee. Indeed, the Everglades community as a whole is rare and endangered by drainage and alteration by man. The everglades habitat under Federal control provides the only sanctuaries into which humans are not allowed and Loxahatchee comprises one of the last unaltered sections of the Everglades. These refuge lands will continue to harbor the basic plant communities of the glades after

other sections no longer exist. Another plant, the cowhorn orchid or butterfly orchid (Cyrtopodium punctatum), listed as threatened by the Florida Committee, was once wide-spread in Cypress swamps in South Florida, including Loxahatchee. It has been virtually eliminated by collectors but re-introduction into suitable habitat would be possible.

Moving northward, Hobe Sound National Wildlife Refuge was one of the last places where Onicidium variegatum, another orchid, was found in abundance in the wild. This species is listed as threatened by the Florida Committee. Re-introduction is a real possibility here since adequate protection could be afforded to get the species reestablished.

In Georgia, we, of course, have the Okefenokee Refuge which contains unique plant communities. The only species I am currently aware of that is included in endangered listings of flora is Pinckneya pubens, which is listed as threatened in the Smithsonian Report.

The umbrella magnolia (Magnolia tripetala) is found in one known location on the Piedmont National Wildlife Refuge and is probably worthy of threatened status, at least at the State level, although not currently listed. Other uncommon plants are found on Piedmont which are not believed to be critically threatened at this time.

In South Carolina, the Carolina Sandhills National Wildlife Refuge contains several plants worthy of mentioning. The sweet pitcher plant (Sarracenia rubra) and the pixie moss (Pyxidanthera brevifolia) are listed as threatened species in the Smithsonian Report. These two species and two others, Sarracenia flava, the yellow pitcher plant, and a hybrid pitcher plant (Sarracenia flava x Sarracenia purpurea) are also listed in the list of Rare and Endangered Vascular Plants of South Carolina. (Unpublished).

Although the above examples do not represent a complete cross section of the National Wildlife Refuge System in terms of states, habitats, etc., I think they do illustrate the role refuges can and do play in conservation of endangered plants.

GRANT-IN-AID PROGRAM

Another way that the Fish and Wildlife Service has played a role in conservation of endangered plants is through the Federal grant-in-aid programs to the states through the Pittman-Robertson Act. Through this program states have purchased over 3-1/4 million acres and manage an additional 51 million acres through leases or licensing agreements (U. S. Fish and Wildlife Service 1975b). Although purchased for wildlife, these areas have also played an important role in conservation of plants, in the same way as the National Wildlife Refuge System. I do not have specific examples to offer but I have complete confidence that numerous unique and threatened species are found on these lands and have benefitted from the management of these lands.

ENDANGERED SPECIES ACT OF 1973

That brings us to recent times and the role of the Fish and Wildlife Service under the Endangered Species Act of 1973 (93rd Congress, S.1983, 1973). The Secretaries of Agriculture, Commerce and Interior all have responsibilities under the Act. However, Agriculture's responsibility is limited to importation and exportation of terrestial plants. The other functions under the act relating to plants are the responsibility of the Fish and Wildlife Service and the National Marine Fisheries Service. No agreement is presently in effect between these agencies as to the division of responsibility for plants.

The role of the Service for plants under the Act is basically four-fold. First is the job of listing and delisting species. Second is the enforcement of the prohibited acts set forth in the Act. These prohibited acts concern import and export of listed species, being a party to commercial activity in these species in interstate or foreign commerce and violation of any promulgated regulation regarding the species.

The third role concerns the reviewing of all programs administered by the Service and utilizing these programs in furtherance of the purposes of this Act. The fourth role under the Act is consultation with all other federal agencies to see that they utilize their authorities in furtherance of the purposes of the Act. These last two roles are spelled out in Section 7 of the Act. It directs all Federal agencies to carry out programs for the conservation of endangered and threatened species listed pursuant to the Act and to take necessary action to insure that actions authorized, funded or carried out by them do not jeopardize the continued existence of such species or result in the destruction or adverse modification of critical habitat of such species.

Another provision of the Act that should be mentioned is that funds made available pursuant to the Land and Water Conservation Fund Act of 1965 may be used for acquiring lands for endangered and threatened species, including plants. Through fiscal year 1975 a total of $16.3 million has been appropriated for acquisitions beneficial to endangered species. Projections for the Fish and Wildlife Service indicate $245 million are needed to acquire 455,000 acres in the next six years to adequately carry out the legislative mandate of the Endangered Species Act (U. S. Fish and Wildlife Service 1976).

At the present time there are no native plants listed as endangered or threatened. However, the Smithsonian Institution prepared a report as authorized by Section 12 of the Endangered Species Act, that listed over 3000 plants as endangered or threatened (Smithsonian Institution 1975). This list is currently being given a status review by the Fish and Wildlife Service and a proposed rulemaking to list many of these plants is now being formulated and should be published in the Federal Register shortly.

DISCUSSION AND SUMMARY

Listing of plants will, of course, place more emphasis on endangered plants and thus, the Fish and Wildlife Service will continue to increase its role in conserving endangered and threatened plants. I think the

material just presented shows that the Service has played a role in the past in conserving plants, although it may have been largely in an indirect way, and this role will expand.

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A COHERENT APPROACH TO THE PROTECTION OF ENDANGERED SPECIES

by

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ABSTRACT

At the State level there are several techniques available to ensure protection of endangered plant species, in addition to acquisition of natural areas. Actual purchase of habitat is certainly one method, but it is expensive and the impact, in terms of the number of species protected is not impressive. Other techniques include managing all state-owned lands for endangered species, educating and assisting private landowners and incorporating endangered species criteria as an integral part of A-95 and NEPA environmental reviews. In order for these efforts to be effective, a systematic and thorough endangered plants inventory, undertaken cooperatively by scientists, citizens and government, must be vigorously pursued.

The assigned topic for this discussion was the "Preservation of Endangered Plant Species Through Natural Areas", and while that is an important tool in state preservation efforts, it is only one of a variety of techniques available to us. It becomes an even more limited tool if one means by "Preservation of Endangered Plant Species Through Natural Areas," the actual acquisition in fee simple of those natural areas. The discussion which follows will be about the State of Georgia's program, what we like to think is a coherent, practical and effective, if fledgling program for the protection of endangered plant species.

In order to protect endangered species, we must protect the habitat, and there are a number of tools available to accomplish this objective. The most obvious and direct approach to protection of habitat is to simply go out and buy it. The Georgia Heritage Trust Program, established in 1972 by Governor Jimmy Carter, is a continuing and systematic acquisition program, designed to identify and rank for public acquisition those lands that best exemplify our natural and cultural heritage. The program is comprehensive in that all land acquisition--for wildlife management areas, parks, historic sites, natural areas, water access, scientific and educational purposes, trails--is channelled through the Heritage Trust. The result is coordination, expertise and flexibility in acquisition heretofore impossible. More importantly multi-purpose use of sites is programmed from the beginning, insuring that the public will derive maximum benefit from the site.

While the presence of endangered species is an important criteria in the acquisition of natural areas through the Heritage Trust program, the Department also looks for areas that are relatively undisturbed, that

retain their natural characteristics and contain populations of plants and animals worthy of protection for educational and interpretive purposes as well as for the simple enjoyment of man.

Panola Mountain State Park, a 537-acre park located 18 miles southwest of Atlanta, is such an area. It is characterized by rock outcrops and contains a number of species endemic to granite outcrops such as Elf-orpine, (Diamorpha cymosa (Nutt.) Britton). Panola is a conservation park with a system of self-guided nature trails and interpretive programs to encourage visitors to listen, watch, smell, taste and spiritually touch a small tract of wilderness.

Through the Heritage Trust Program, the State of Georgia has acquired natural areas in order to protect endangered species in several instances, the most notable example of which was the acquisition of the Phillips Tract or the "Big Hammock Natural Area," a 750-acre tract of land located in Tattnall County in the coastal plain in Georgia.

The Phillips Tract consists predominantly of a Pleistocene (or older) Sand Ridge on the northeast side of the Altamaha River flood plain. The site contains one of the last remaining undisturbed evergreen broadleaf hammocks along the entire border of the Altamaha River Swamp from Tattnall County southeast to McIntosh County. Included in the site is a strip of the Altamaha flood plain on the southwest border, and a series of drainageways on the northeast side that are dominated by Pond Cypress (Taxodium ascendens), Black Gum (Nyssa sylvatica), Ogeechee Lime (Nyssa ogeche), and Wax Myrtle (Myrica cerifera).

There are several unique features associated with this sand ridge. The forest contains the largest breeding population of Georgia Plume (Elliottia racemosa) known to exist, and the largest population or stand of Myrtle Oak (Quercus myrtifolia) known to occur in the interior of Georgia (Bozeman, 1971).

The Georgia Plume is presently found in only eight counties in the State of Georgia. The plant is a primitive member of the Heath Family (Erecaceae) with its closest relatives found in Japan (Wood, 1961). It grows commonly as a shrub or small tree and requires a sandy, well-drained soil. Attempts at transplanting this species for the horticultural trade have been quite unsuccessful for over a decade since the plant can be propagated only rarely by seed, and with some difficulty by root sprouts.

The most important aspect of this tract of land is that it contains more plants of Georgia Plume than all the other known populations combined. These plants, which inhabit more than 400 acres in this site, consistently produce more seed than other known populations, a possible reflection of the genetic variability and vitality of the populations. This site is truly a one-of-a-kind, last-of-its-kind, which must be protected.

The myrtle oak (Quercus myrtifolia) is a characteristic shrubtree of the Sand Pine-Scrub forest of the Central Highlands Region of Florida (Laessle, 1958). It has a sporadic distribution almost entirely limited to the Lower Coastal Plain in Georgia where it occurs on marine bars and alluvial sand hammocks of Pleistocene age (Bozeman, 1971). This stand of myrtle oak represents the most inland and most extensive population in the Atlantic Coastal Plain, north of Florida and could very well be a Pleistocene relic.

From the State perspective, management of this site for public education and enjoyment, while preserving and enhancing the resources for which it was acquired,represents a tremendous challenge. Currently, use of the area is limited to educational and research activities with visits by various universities and colleges allowed.

Obviously, acquisition of habitat is the most effective means of protection. Management for preservation is ensured. But what are the limitations of this approach? The answer is largely told in dollars and cents and the story is exemplified by the Georgia Heritage Trust Program. In 1973, at the program's inception, the Georgia General Assembly appropriated $12.5 million for the Heritage Trust and we maintained that an appropriation of that magnitude was needed for at least ten years in order to preserve endangered pieces of Georgias natural and cultural legacy. In 1974 the appropriation to Heritage Trust was $538,449; in 1975, $590,000; and in 1976 $50,000. Economic hard times hit State government severely. The Department of Natural Resources suffered budget cuts of 1.7 million in FY 1976. We bit the bullet, but clearly the message was that many programs would suffer. This was true for many Departmental programs of long-standing as well as for newer and more tentative programs such as Endangered Species Protection.

Even in times of economic growth and well-being, a single-minded approach to protection of endangered species through acquisition would likely fail. There are always limited resources and competing demands. Political support for a large number of single-purpose acquisitions would be unlikely, and, the management problems created by a large number of sites required to protect an endangered or threatened species would be awesome. Even if the State selected sites for maximum density, the impact in terms of the number of species protected would not be that impressive.

We have found, however, that in thinking about the problems I have enumerated above that there are workable alternatives to outright purchase which will result in an effective and vital endangered species program in Georgia.

Certainly, the first task is to ensure that protection of endangered plant species is a criteria in all purchase and management of state-owned land. On property already owned by the State we are adopting management objectives emphasizing a conscious application of the principles of management for the protection of endangered species.

It was through our Systems Planning and Master Planning efforts that we discovered the need to intensify management of state-owned land for protection of endangered species. We have just completed a Parks and Historic Sites System Plan which identified a need to assess the presence of rare or endangered species on all property--that property proposed for acquisition and that already in State ownership. General Development Plans, developed for each park in the State system, indicate the actual physical location of these areas on the park maps. These sites are then designated as "Special Management Areas," and detailed prescriptions for management are drawn up and given to the Park Superintendents to guide their protection efforts. Endangered species experts are prepared to go to these sites to sensitize and train on-site managers to the principles of management for protection of rare and endangered species located in their parks. At Reed Bingham State Park, the Superintendent recently burned a pitcher plant bog. Fortunately, in this case, he took the appropriate action. But it illustrated for us the vital need to educate some fifty Park Superintendents located all over the State, about proper management techniques for endangered species protection.

We anticipate Systems Plans for Wildlife Management Areas and Natural Areas, which will incorporate among their objectives emphasis on preservation of endangered species. General Development Plans, undertaken for each site will, as in the case of Parks, provide prescriptions for Special Management Areas.

Wildlife Management Areas represent real opportunities for special management. Generally, wildlife management areas are large tracts of land often containing a number of natural areas deserving special treatment.

A good example of this kind of opportunity is the Lewis Island Tract on the Altamaha River in McIntosh County. This 5,500-acre tract containing the only known stand of virgin cypress in the State is part of the 18,000-acre Altamaha Waterfowl Management Area. In the future, in addition to being managed for waterfowl, it will represent an important natural and interpretive area.

With the knowledge that we can never hope to acquire all of the habitat necessary to protect threatened or endangered species we will continue to acquire critical pieces of land, like the Phillip's Tract and Lewis Island, and to manage our own land with protection as a major objective.

But a second thrust, and perhaps an even more important one in the long term, involves our work with landowners across the State. In order to be truly effective, the State must work closely,advising and assisting private landowners about the presence and proper management of endangered plant species on their property. That, in turn, necessitates a well publicized and free exchange of information among scientists, landowners,

and the public in general in order to identify and locate species that warrant protection.

A dramatic example of the possibilities of this cooperative approach can be illustrated by our work with a major timber company on the Altamaha River in Southeast Georgia. The area under study involves 250,000 acres of land and 64 river miles along the Altamaha River. The property contains representatives of approximately 12% of the plants and animals on the State list of endangered or threatened species. We have already identified nine species of animals that are on the State list of endangered animals including the Short-Nosed Sturgeon, the Alligator, the Eastern Brown Pelican, and the Southern Bald Eagle, among others. There are likewise at least ten endangered plants that we have either seen or suspect because of appropriate habitat including Pond Spice (Litsea aestivalis) and Swamp Holly (Ilex amelanchier). Our job is to identify areas for special management and to propose the form that the special management should take; whether it be buffer strands along the shoreline or natural areas inland from the river that should not be timbered, or which should be burned, or which need some kind of special prescription. It is very likely that some of the shoreline buffer strands will be donated to the State to manage. However, we are hopeful that some of the inland sites which will remain in private ownership will be managed by prescriptions prepared by State botanists and biologists.

Another example of a request for assistance involved a private industry with headquarters on the Chattahoochee River. They owned habitat appropriate for several endangered plant species and contacted the Department for assistance in establishing a natural wildflower garden emphasizing rare or endangered plants. The property consists of 70 acres of upland hardwood that will probably support pink and yellow lady slippers and a variety of rhododendrons.

In order for the State to take advantage of these opportunities and in order for us to initiate cooperation with landowners, we must do several things. First, we must maintain a diligent and continuing program to inventory endangered species. Within the Department of Natural Resources we have two major programs that address this need. The Natural Areas Unit, through information made available by the State Resources Assessment Program (including topographic maps, soils and vegetation maps and aerial photographs) identified those environments where populations of endangered species are likely to occur. Using that information and following leads provided by fellow botanists and concerned citizens, the Natural Areas Unit conducts field inspections of each site.

A file is maintained on each site. Such an inventory is critical for identifying populations of endangered species that might be destroyed by various development projects. One of the most critical tasks before us now is developing the capability to work with developers in the planning stages of their projects by assisting them in the development of alternatives that lessen the impact of human expansion on endangered species. A good example of the need for this capability is the Appalachian Highway Project or Georgia 400, a development highway proposed for North Georgia.

In the fall of 1975, the Department of Natural Resources reviewed the Draft Environmental Impact Statement for this project. Five alternative routes were described in the Draft EIS and a list of endangered plants accompanied each alternative. They were not located on a map and our inventory was not adequate to assess the accuracy of the list. But the real issue here is that we should have been looking at the problem long before, when the alternatives were being formulated. With an adequate inventory we could have recommended routes that would have avoided critical colonies of endangered species. We must develop that capability.

Our greatest need in Georgia now is to concentrate our efforts on a systematic inventory of endangered plants in our State. The Department, through its environmental review of Federally-supported projects that occur in Georgia, can have a tremendous impact on protection of endangered species. But we must know where they are. We must begin to seek more information and assistance from scientists and we must encourage the public at large to share information.

In the context of our review of federally assisted projects in the State, we must encourage major land-holding Federal agencies in our State, such as the U. S. Forest Service, to identify and designate special management areas within the national forests. While management of the Chattahoochee National Forest seems to be increasingly sympathetic to these kinds of concerns, it is our duty as the state natural resources agency to assist them in data-gathering and to advise them about special management for protection of endangered species.

Section 404 of PL 92-500 mandated that the Federal government issue permits for the discharge of dredged or fill material into navigable waters. This three-phased program, administered by the U. S. Army Corps of Engineers, will eventually require permits for any dredging activities on any stream or wetland in the entire State. As you know, coastal and inland wetlands represent niches that are often rich with endangered or endemic species. This program represents a real opportunity to protect endangered species through our review process.

But the entire program has been threatened in the House by the introduction of the Breaux Amendment to H.R. 9560, which would redefine navigable waters to include only those waters that support interstate or foreign commerce. If we lose the 404 program, we lose a major tool for protecting endangered species.

Another major thrust of our efforts must be toward implementing the Federal Endangered Species Act, which required that once a species is identified as endangered, a management plan must be established to restore the species. We must use publicly owned lands in that effort and we must acquire public lands with that objective in mind. As a small part of that effort, the Natural Areas Unit is establishing a catalog of habitats available for transplanting. The physical

parameters of each site are described in great detail, so that if destruction of an endangered plant is inevitable, it can be moved to an appropriate site.

We also need to turn our efforts to enforcing the rules and regulations already in existence for protection of endangered plants. The Board of Natural Resources has adopted "Rules and Regulations for the Protection of Endangered, Threatened, Rare or Unusual Species". These regulations officially designate a list of plants and animals which will be protected in Georgia and provide a procedure for nomination to the list. Removal of any protected plant species from public land is prohibited unless permitted by the Department. Sale of any protected plant species is prohibited unless the plant was grown on private land and is being sold by the landowner or with the permission of the landowner. Furthermore, removal of protected plants from private land is forbidden without a permit from the Department and written permission from the landowner.

These regulations will provide us with a means to regulate collecting, a practice, which as frequently as transportation projects destroys colonies of endangered plants.

Clearly, we have many tools at our disposal to ensure protection of endangered plant species. But if we are to be truly effective, we must work together in our efforts. Scientists must work with public officials and public officials at the State level must take the initiative with private landowners and must encourage a sensitive attitude on the part of other State agencies and Federal agencies. We must understand together what and where the resources are that we want to protect and how we want to protect them. Then we will be able to make coherent and informed decisions about the future of these resources.

THE STATE NATURAL HERITAGE PROGRAMS

Robert M. Chipley[1/]

Abstract.--The Nature Conservancy has established the State Natural Heritage Programs to create a systematic process for the management and analysis of ecological data on the elements of natural diversity, which include plant community types, aquatic types, and endangered, threatened and rare flora and fauna. The programs are conducted in cooperation with an agency of the state government. In the Southeast, programs are currently underway in North Carolina, South Carolina, Tennessee, Mississippi, and West Virginia.

There are scientific, practical, and esthetic reasons for wanting to preserve genetic diversity. The purpose of this brief presentation is to point out that, in the case of endangered plants, we can at least come close to this goal, if the task is approached systematically.

Since endangered plants are rarities, frequently confined to unusual or marginal habitats, this means that this ten percent of the flora occupies a very limited amount of ground, probably less than one percent of the land mass (Jenkins 1975). A minimum system of preserves, if accurately aimed at this fraction of the landscape, could probably perpetuate most of these species. The problem becomes, then, the systematic identification and protection of the habitats most critical for this fraction of the American flora.

At The Nature Conservancy, our approach toward the problem of identification and protection of critical habitats has been to create what we term the State Natural Heritage Programs. At present, five of our eight programs are in the Southeast, so we have a particular interest in and commitment to this part of the country. The states in which we currently have ongoing or forthcoming programs are North Carolina, South Carolina, Tennessee, Mississippi, and West Virginia. The stated purpose of the program is to preserve, in the greatest degree possible, the spectrum of natural diversity which exists in the state. The programs are generally conducted under a one-year contract or memorandum of agreement with an appropriate state agency, such as the state department of conservation. At the end of one year, a comprehensive system for the accession, management and analysis of ecological data is delivered to the state.

The Heritage Program generally consists of four phases. These are (1) Program Development, (2) the Pilot Inventory, (3) Protection Planning, and (4) Program Continuation and Implementation.

PROGRAM DEVELOPMENT

Program Development involves hiring and training the program staff, setting up the office in the state, creating a classification system of what we term the elements of diversity, and installing the data management apparatus. The last two points are the core of the methodology, and will be further elaborated.

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Classification System

The purpose of the classification system is to create a listing of what we term the elements of natural diversity occurring in the state. As defined by the program, an element is a natural feature of particular interest, either because it is unique or endangered within the state or nationally (such as the Tennessee Cone Flower) or because it represents an important type (such as the Cypress-Tupelo Swamp). The purpose of the classification system is to identify, define, and catalog these elements by class. This structure forms the basis for the orderly gathering of information during the inventory phase of the program. Initially, the classification system will involve a hierarchical ordering of plant communities and aquatic types, and a listing of special species (including those which are endangered, threatened, rare, endemic, peripheral, or otherwise of particular concern and interest). The system may be expanded to include geological, historical, archeological, and other classes of elements. In addition, as further information becomes available, new elements may be added under each class, and some existing elements may be redefined, broadened, or subdivided. The classification is completed with the input of in-state experts, previous scientific work and already existing national and state classification schemes. The underlying assumption of the classification is that, if we can locate protected examples of each of the described types and species, we will have gone a long way toward preserving the natural diversity of the state.

Data Management System

Information is collected and stored on an element-by-element rather than site-by-site basis. The data management system consists of two components: the manual files and the computer-assisted Lowest Common Denominator File. The extensive manual files contain information on each of the elements in the classification, map files for maintaining and displaying the localities of the various elements, aerial photos, and other pertinent information. The computer-assisted Lowest Common Denominator Element File is designed to incorporate efficiently the minimum amount of data necessary for analysis of the location and characteristics of occurrences of the elements, and direct the user to the manual files only if further information is desired. Minimum data includes the name of the area on which the element is found and its geographical coordinates, the name of the owners and the protection status of the area, the size, and items of general description. This information can be accessed in any of several combinations, depending on the needs of the system-user.

PILOT INVENTORY

This phase of the program involves the actual collection of data on the elements described in the classification, and the entry of this data into the data management system. Initially leads are generated by reviewing earlier inventories, the general literature, consulting with experts, and investigating museum collections. As these leads are generated, a preliminary analysis will guide the program staff toward information gaps, that is, the types of elements for which we have little or no data. Using this "gap analysis" we will be able to concentrate our data gathering on the types for which we have the least information. At some point in the program, when existing information has been largely exhausted, we can more efficiently target our priorities for conducting in-depth field surveys.

The major outcome of this task is the setting into motion of the data-gathering process. The information flow will be started and established for the continuing operations of the program.

PROTECTION PLANNING

This phase of the program involves planning for the protection of the ecological elements identified during the inventory. This phase is done independently of the first two phases of the program in that it can be completed during the early stages of the program or near the end of the pilot inventory. The major product of this phase will be the survey of existing and potential protective mechanisms for ecological resources and natural areas in the state.

PROGRAM CONTINUATION AND IMPLEMENTATION

By the end of the contract period, the state should have at its disposal a continuous process of ecological inventory, data management, and protection planning for the preservation of its natural heritage. At this point, the Conservancy's role changes in scope from an operational to an advisory capacity. The Conservancy will ensure that the transition to state management will be a smooth one, and that any further improvements in methods and technology will be made available to the state.

APPLICATIONS OF INVENTORY DATA

The inventory data can be analyzed and applied toward several uses, depending on the needs of the data requestor. For preservation purposes, we may wish to know which natural elements are the rarest and most vulnerable in the state; we therefore ask the system to tabulate the number of reported occurrences for given elements, and to tell us whether or not they occur on protected sites. We may then choose the element, such as an endangered plant, with the fewest or no reported occurrences on protected lands as a prime candidate for the limited funds at our disposal.

A further application will be in the field of environmental impact assesment, long hindered by a lack of state, regional, or national perspective. The criticality or significance of any individual site (or alterations to the site) cannot be judged by reference to that site alone. If, however, comparable data exists on many sites, systems, or features within the state, one can gain the perspective necessary for estimating the relative significance of any single site. The Heritage system will provide the structure and methodology for collecting the standardized data by which such comparisons and evaluations can be made.

Another use will be for planning purposes. A state or municipal agency may wish to know which areas are ecologically significant within a certain district; by use of overlays, the system can display ecological information in relation to other land-use parameters such as agriculture, corridors, and urban districts.

One important feature of the computer system is its flexibility. We have practically no set analysis patterns but can rather adjust to fit the needs of the system-user. In other words, if a request is made by a valid user for data on a particular species, we will be able to produce a map of the locations for the species, and a print-out with the general description, size, and owner-

ship of each site where it occurs, when the site was last surveyed, the source of lead for each occurrence, or any combination of these. If information is requested on a county-by-county or grid basis, the computer is able to sort out the requested data. The option exists within the system for suppressing locality information.

It is important to note that, in the State Natural Heritage Programs, the most important product is the process itself. Our goal is to establish a cooperative effort between the public and private sectors for the identification and protection of those areas which best represent the state's natural heritage.

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NATURAL AREAS IN THE APPALACHIAN SECTION REGISTERED WITH THE SOCIETY OF AMERICAN FORESTERS

Keith A. Argow[1/]

The Natural Areas program of the Society of American Foresters includes the continental United States, Hawaii, and Alaska. The program is administered by geographic sections recognized within the SAF. My comments today are directed towards the Appalachian Section, which in our context includes Virginia and North and South Carolina. Since this is a conference on endangered plants throughout the Southeastern U.S., it should be noted that similar SAF programs are operative in the Tennessee-Kentucky section, the Florida section, the Georgia-Alabama section, and the Gulf States section.

In addition it should be noted that the SAF Natural Areas system is founded upon forest types, as might be expected with a professional forestry society. The program is based upon the publication <u>Forest Types of North America</u> published in 1954 by the SAF. This descriptive guide is in the process of revision now; however, we anticipate few major changes in type classifications. Although established to protect forest types, SAF Natural Areas also protect the flora and fauna inherent in their ecosystems.

The forests of Virginia and North and South Carolina are diverse. They range from the spruce-fir caps of the Smokies to the sand live oak-cabbage palmetto forests of the South Carolina coastal plains. Three physiographical zones are recognized: Appalachian Mountains, Piedmont, and Coastal Plains. Within these three States at least 55 separate forest types occur. This number may be higher due to the possibility that some southern forest types not included in the tally do extend into the coastal plain and some central forest types extend east into Virginia and North Carolina. The SAF has registered a total of 47 natural areas in the section encompassing some 42 forest types. A list of forest cover types occurring in SAF Natural Areas in the Appalachian Section is appended to this paper.

Although at first glance our system would appear to be quite complete, 13 forest types are not represented at all. Noteworthy among the omissions are sugar maple, eastern red cedar, yellow-poplar (pure), longleaf pine, Virginia pine, and pondcypress.

Nineteen forest types are represented only once. Among this group are black cherry, red spruce (pure), scarlet oak, black locust, white oak, northern red oak, shortleaf pine-oak, and water tupelo.

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The Purpose of Natural Areas

The SAF Natural Areas system has been established primarily for research purposes. They are "control areas," tracts of land where nature is allowed to take its own course. They provide useful silvicultural and other information about what happens in southeastern forest types when they are unmanaged. By comparing data, we can gage the influence and results of forestry management practices relative to natural ecosystems.

The goal of the Appalachian Section Natural Areas committee is to reserve two representations of each type occurring in the section. Some species which have a wide range and exhibit regional and site variations will require multiple representations within the system to be adequately represented (i.e., loblolly pine).

History of SAF Appalachian Natural Areas

The first tract of land in the Appalachian Section to be set aside for a natural area was Black Mountain, North Carolina. A part of the Pisgah National Forest, this 1,400-acre natural area on the east slope of Mount Mitchell was established by the U.S. Forest Service in 1933. Ramsey's Draft and Little Laurel Run--both on the George Washington National Forest in Virginia--followed in 1935 and 1937, respectively.

When the committee on natural areas was organized by the president of the SAF in 1947, the first mechanisms were established for SAF registration of natural areas. By 1949 the three foregoing U.S. Forest Service Natural Areas, plus two more areas established by the U.S. Fish and Wildlife Service, became a nucleus of the SAF Natural Areas within the Appalachian Section.

In the National committee's first report, Chairman John F. Shanklin noted that the program had been initiated upon the recognition by the SAF Division of Silviculture that practicing foresters needed a "more comprehensive knowledge of natural developments within virgin forest associations." Shanklin also noted that the action establishing the Committee on Natural Areas came "very late in our Nation's forest development history" and effective action was long overdue.

It became apparent to the new committee that the southern region of the United States was in most need of attention. To this end a grant was secured from Resources for the Future, Inc., to conduct a survey for potential natural areas. F. H. Eyre was appointed project leader and conducted an extensive field reconnaisance. In 1960 the "Survey of Proposed Natural Forest Areas in the Southeast" was published by the SAF.

Inventory and Ownership

Aside from the Eyre report, the SAF has not conducted extensive inventories of natural ecosystems *per se*. These projects, which can be quite extensive and expensive, are left to State agencies, universities, and national organizations such as the natural heritage inventory program con-

ducted by the Nature Conservancy. The intent of the SAF Natural Area program is to give recognition through registration of significant natural tracts.

The Society of American Foresters does not seek ownership of the areas it registers. In fact, the SAF Natural Area program is entirely a voluntary registration which can be canceled by either party rather readily. More permanent protection is encouraged through formal action by private landowners in designating public lands as research natural areas, botanical areas, etc. If public ownership or some other form of protection of a natural area is desirable, then the assistance of a public agency or the Nature Conservancy is sought. A particular advantage in utilizing the Nature Conservancy is that it maximizes the tax benefits to the private landowner while at the same time preserving the area on the best terms available.

Administration of SAF Natural Areas

Basic responsibility for administering a natural area lies with the landowner. Most public agencies have ample regulations to accomplish this. Some conflicts do arise however in the area of public use, principally recreation. For this reason it is recommended that SAF Natural Areas not be designated on recreation use maps. If they are, a paragraph describing their purpose and the potential damage due to overuse is encouraged on the backside of the map.

Natural areas are not extensively signed. There is a small SAF boundary marker intended for use only on the main access routes. Boundary painting may be appropriate in areas where adjacent lands are under extensive management. Moreover, little publicity is recommended for these areas.

A current listing of natural areas including maps and information relative to ongoing research, etc., is maintained by the national office of the Society of American Foresters in Bethesda, Maryland. Many chapters also maintain current lists. Here in the Appalachian Section, we publish the Appalachian Natural Areas Directory. This publication carries maps, descriptions, and pertinent information for each natural area registered within the three States. It is intended as a method of communicating this information to forest researchers and others who have reason to be interested in the natural area system.

The Natural Areas Committee of the Appalachian Section is hopeful that at least some endangered plants are already represented in our growing natural areas system. We welcome your suggestions on expansion and look forward to working with you.

Attachment:

1. Appalachian Natural Areas Bibliography.

2. Summary of Forest Types Represented in Appalachian Section Natural Areas. 1976.

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APPALACHIAN SECTION NATURAL AREAS - 1976

Summary of Forest Types Represented

VIRGINIA

1.	Charles C. Steirly	SAF 102 Baldcypress - water tupelo, 19 ac.
2.	Chestnut Ridge	SAF 41 Scarlet oak, 18 ac. SAF 87 Sweetgum - yellow-poplar, 6 ac.
3.	Chincoteague	SAF 87 Loblolly pine - hardwood, 135 ac. Swamp and marshy area, 15 ac.
4.	Clinch Mountain	SAF 29 Black cherry, 23 ac.
5.	Holiday Creek	SAF 75 Shortleaf pine, 2 ac. SAF 77 Shortleaf - Virginia pine, 17.5 ac. SAF 87 Sweetgum - yellow-poplar, 10.5 ac.
6.	Lick Creek	SAF 23 Hemlock, 30 ac. SAF 58 Yellow-poplar - hemlock, 30 ac. SAF 59 Yellow-poplar - white oak - no. red oak, 430 ac. SAF 78 Virginia pine - southern red oak, 180 ac.
7.	Little Laurel Run	SAF 21 White pine, 45 ac. SAF 23 Hemlock, 127 ac. SAF 44 Chestnut oak, 445 ac. SAF 45 Pitch pine, 89 ac. SAF 59 Yellow-poplar - white oak - no. red oak, 62 ac. Barren and brush, 1,324 ac.
8.	Mount Rogers	SAF 25 Sugar maple - beech - yellow birch, 820 ac. SAF 34 Red spruce - Fraser fir, 332 ac. Meadow grass and fern, 148 ac.
9.	Mountain Lake	SAF 23 Hemlock, 75 ac. SAF 24 Hemlock - yellow birch, 100 ac. SAF 30 Red spruce - yellow birch, 60 ac. SAF 43 Bear oak, 935 ac. SAF 54 No. red oak - basswood - white ash, 433 ac.
10.	Ramsey's Draft	SAF 23 Hemlock, 177 ac. SAF 25 Sugar maple - beech - yellow birch, 89 ac. SAF 44 Chestnut oak, 442 ac.

10.	<u>Ramsey's Draft</u> (continued)	SAF 45 Pitch pine, 26 ac. SAF 52 White oak - red oak - hickory, 991 ac. SAF 55 Northern red oak, 169 ac. SAF 59 Yellow-poplar - white oak - no. red oak, 67 ac.
11.	<u>Rock Quarry</u>	SAF 52 White oak - red oak - hickory, 27 ac. SAF 87 Sweetgum - yellow-poplar, 13 ac.
12.	<u>Roland-Bull Run Mountain</u>	SAF 59 Yellow-poplar - white oak - no. red oak, 20 ac. Brush, 2 ac.
13.	<u>Swift Creek</u>	SAF 52 White oak, 17 ac. SAF 61 River birch - sycamore, 5 ac. SAF 81 Loblolly pine, 26 ac. SAF 82 Loblolly pine - hardwood, 10 ac.
14.	<u>Turkey Ridge</u>	SAF 40 Post oak - black oak, 16 ac.
15.	<u>Willis River</u>	SAF 93 Hackberry - American elm - green ash, 38 ac.

NORTH CAROLINA

16.	(1) <u>Black Mountain</u>	SAF 17 Pine cherry, 13 ac. SAF 25 Sugar maple - beech - yellow birch, 126 ac. SAF 34 Red spruce - Fraser fir, 542 ac. SAF 44 Chestnut oak, 229 ac. SAF 52 White oak - red oak - hickory, 419 ac.
17.	(2) <u>Chowan River</u>	SAF 101 Baldcypress, 10 ac. SAF 102 Baldcypress - water tupelo, 49 ac. SAF 103 Water tupelo, 15 ac.
18.	(3) <u>Duke Forest</u>	SAF 52 White oak - red oak - hickory, 27 ac. SAF 81 Loblolly pine, 59 ac. SAF 82 Loblolly pine - hardwood, 57 ac. SAF 87 Sweetgum - yellow-poplar, 8 ac.
19.	(4) <u>Great Lake</u>	SAF 98 Pond pine, 60 ac.
20.	(5) <u>Hemlock Bluffs</u>	SAF 23 Hemlock, 1 ac. SAF 44 Chestnut oak, 5 ac. SAF 82 Loblolly pine - hardwood, 14 ac.
21.	(6) <u>Hill Forest</u>	SAF 75 Shortleaf pine, 9 ac. Buffer zone, 1 ac.

22. (7) <u>Hofmann Forest Cypress</u>	SAF 101 Baldcypress, 20 ac. SAF 104 Sweetbay - swamp tupelo - red maple, 8 ac.
23. (8) <u>Kelsey</u>	SAF 22 White pine - hemlock, 72 ac. SAF 59 Yellow-poplar - white oak - no. red oak, 90 ac.
24. (9) <u>Little Santeelah</u>	SAF 23 Hemlock, 500 ac. SAF 59 Yellow-poplar - white - no. red oak, 3,000 ac.
25. (10) <u>Milltail Creek</u>	SAF 97 Atlantic white-cedar, 36 ac.
26. (11) <u>Nere Elexus Day Pond Pine</u>	SAF 98 Pond pine, 25 ac.
27. (12) <u>North Fork</u>	SAF 34 Red spruce - Fraser fir, 200 ac.
28. (13) <u>Piedmont Beech</u>	SAF 52 White oak - red oak - hickory, 21 ac. SAF 81 Loblolly pine, 25 ac.
29. (14) <u>Piney Knob Fork</u>	SAF 22 White pine - hemlock, 60 ac.
30. (15) <u>Rocky River White Pine</u>	SAF 21 White pine, 10 ac.
31. (16) <u>Rough Creek</u>	SAF 50 Black locust, 18 ac. SAF 52 White oak - red oak - hickory, 5 ac.
32. (17) <u>Salyer's Ridge</u>	SAF 81 Loblolly pine, 75 ac.
33. (18) <u>Schenck</u>	SAF 82 Loblolly pine - hardwood, 25 ac.
34. (19) <u>Three Forks</u>	SAF 24 Hemlock - yellow birch, 2,203 ac. SAF 30 Red spruce yellow birch, 2,030 ac. SAF 32 Red spruce, 2,632 ac. SAF 34 Red spruce - Fraser fir, 4,372 ac. SAF 44 Chestnut oak, 826 ac. SAF 58 Yellow-poplar - hemlock, 1,377 ac.
35. (20) <u>Turkey Oak</u>	SAF 72 Southern scrub oak, 90 ac. pocosin, 43 ac.
36. (21) <u>Upper Piedmont Research Station</u>	SAF 44 Chestnut oak, 4 ac.
37. (22) <u>Walker Cove</u>	SAF 25 Sugar maple - beech - yellow-poplar, 55 ac.
38. (23) <u>Windy Falls</u>	SAF 51 White pine - chestnut oak, 103 ac.

SOUTH CAROLINA

39.	(1) Boiling Spring	SAF 82 Loblolly pine - hardwood, 9 ac.
40.	(2) Bulls Island	SAF 74 Sand live oak - cabbage palmetto, 500 ac. SAF 82 Loblolly pine - hardwood, 500 ac.
41.	(3) Coon Branch	SAF 58 Yellow-poplar - hemlock, 15 ac.
42.	(4) De La Howe Shortleaf Pine	SAF 76 Shortleaf pine - oak, 120 ac.
43.	(5) Gulliard Lake	SAF 92 Sweetgum - Nuttall oak - willow oak, 4 ac. SAF 102 Baldcypress - water tupelo, 14 ac.
44.	(6) Juniper Bay	SAF 97 Atlantic white-cedar, 10 ac.
45.	(7) Little Wambaw Swamp	SAF 102 Baldcypress - water tupelo, 60 ac.
46.	(8) Scrub Oak	SAF 71 Longleaf pine - scrub oak, 39 ac. SAF 72 Southern scrub oak, 8 ac. SAF 92 Sweetgum - Nuttall oak - willow oak, 2 ac. Marshland, 3 ac.
47.	(9) Wassamassaw	SAF 102 Baldcypress - water tupelo, 7 ac. Water, 3 ac.

DETERMINING DISTRIBUTION

Roy B. Clarkson[1]

Abstract. -- A knowledge of distribution and abundance is essential to decisions concerning the rarity of a taxon. Useful aids in determining distribution are regional manuals, monographs, books, scientific papers, regional herbaria, local floras, and local herbaria. The final determination of distribution and abundance depends on continuing field work to determine population dynamics.

Additional Keywords: Regional manuals, monographs, regional herbaria, local floras, local herbaria, field work.

It is obvious that a knowledge of the distribution of a taxon lies at the center of an understanding concerning its rarity. The expression "rare & endangered" is explicit in its implications concerning distribution and abundance. The term distribution implies not only the broad range of the taxon but also its occurrence with these limits.

DETERMINING RANGE

Determining the known geographic range is an important step in achieving an understanding of distribution. Several important aids are available for this task.

Regional Manuals. -- Many individuals have a tendency to turn to regional manuals such as Gray's Manual of Botany, 8th Ed. (Fernald, 1950), New Britton and Brown Illustrated Flora (Gleason, 1952), or Manual of the Southeastern Flora (Small, 1933) and accept the distributions given as describing the range of a taxon. Such manuals are very helpful, however, the weakness noted below should be kept in mind.

The most important consideration in interpreting distributions given in regional manuals is the date of publication. A manual may become outdated very quickly, especially in areas receiving intensive field work. A second inherent weakness in manuals covering a large geographic area is the lack of detail given in the distributions. For example, the range of a naturalized shrub, Scotch Heather, (*Calluna vulgaris* (L.) Hull) is given by Fernald (1950) in Gray's Manual, 8th Ed. as "Peaty or damp sandy spots, always of small extent, very locally from Nfld., to Mich., S. to N.S., N.E., N.J. and mts. of W.Va.". At first reading this would appear to be a rather widespread plant, however, when detailed studies of actual populations are made this plants shows a remarkably disjunct distribution and is seen to be rare in every part of its range.

Despite these weaknesses, regional manuals, even old ones, are valuable tools for they call attention to taxa needing additional study and provide a starting place for such study.

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Monographs, Books, Papers: Valuable supplements to distribution information found in regional manuals are found in monographs, other books, and research papers. Monographs concerned with plant systematics and/or plant geography usually contain detailed distribution data. These data are often summarized in distribution maps. Such data are invaluable in updating known distributions. Access to many monographs prepared in the United States as doctoral dissertations may be had through University Microfilms, Inc., Ann Arbor, Michigan. Pertinent material from many monographs are published in such journals as Taxon, Brittonia, American Midland Naturalists, and Castanea or in book form.

Several excellent books contain distribution information and/or maps. These are usually restricted to plants with a limited distribution or to particular plant types. Examples of these are: Harlow & Harper, 1968; Polunin, 1959; Good, 1964; Meusel, et al, 1965; Hulten, 1958, 1968; Little, 1971; Brown & Brown, 1972; and Critchfield & Little, 1966. The date of publication of such books is again an important consideration in interpreting the distribution data. "Index Holmensis" (Tralau, H., 1969, 1972), an index to distribution maps with world-wide and bibliographic references is an especially valuable source of information.

Regional Herbaria: Large regional herbaria have facilities for study and may lend specimens. These provide a basis for updating range information for specimens representing important range extensions are often sent by the collectors to these centers. Names and addresses of herbaria are found in Index Herbariorum (Lanjouw & Stafleu, 1965).

LOCAL DISTRIBUTION

It is on the local level that the rarity of a taxon is determined. The number of known populations, and the location, size and dynamics of the population can only be determined locally.

Local Floras: Recent local floras such as Flora of West Virginia (Strausbaugh & Core, 1970), Manual of the Vascular Flora of the Carolinas (Radford, Ahles, Bell, 1968) and Flora of Missouri (Steyermark, 1963) are excellent sources of distribution data.

It is difficult to remain current in assessements of plant distribution, even at the local level. For example, since the revision of Strausbaugh & Core's Flora of West Virginia (Vol. 1-4, 1970-1974; Vol. 4 in press) over 20 taxa new to the State have been discovered. Several of these new records extend the known ranges. West Virginia is a relatively small, well botanized area. Larger, less botanized areas may expect a greater number of additions to there flora in a relatively short period of time.

Local Herbaria: Local herbaria are indispensable in distribution studies. Many herbaria have distribution maps for taxa collected in the region. These are useful for quickly checking the overall distribution. Many considerations are necessary in the interpretation of such maps, such as: How well has the area been botanized? Are collections recently made or are the herbarium collections outdated? How widespread are the populations sampled? If collections are sufficient the distribution of the plant may be considered well known, particularly if the taxon is easily seen in the field and identified or if its habitat is restricted to well defined limits.

However, if the taxon is difficult to see in the field, hard to identify

and/or grows in a variety of habitats the distribution may be much more extensive than herbarium vouchers indicate. The distribution of such plants may be considered as undetermined until further field work elucidates the distribution and abundance. Many grasses and sedges are in this category.

The local herbarium is also useful in establishing relevant facts concerning habitat, size of populations, date of collection, and abundance. These facts are necessary to decisions concerning the rarity of the taxon.

UPDATING INFORMATION

Field Work: Manuals, monographs and herbaria all have a tendency to become static, unless continued efforts are made to update and revise records. All too often field work is de-emphasized in an institution after many years of activity. This allows the collections to become outdated and of limited value as time progresses. Only through vigorous and continuous field work can an up-to-date knowledge of the status of populations be determined. A forest fire, an access road or any of dozens of other things can obliterate or greatly restrict a population. Only through careful assessment of the population dynamics of a taxon can its survival probability be determined.

PROBLEMS

One of the greatest problems in determining distribution involves nomenclature. Synonomy at the generic, specific and sub-specific levels makes comparisons of lists of endangered and threatened species very difficult. For example a genus is listed as *Aureolaria* in six state lists, *Gerardia* in six other lists and *Agalinis* in five additional lists. (John Kartez, personal interview). At the lower taxonomic levels the problem is even greater. A need for standardization of nomenclature is very pressing.

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STUDIES ON THREATENED AND ENDANGERED FOREST RELATED SPECIES OF THE SOUTHEASTERN AREA--A PROGRESS REPORT

Robert Kral [1/]

Abstract.--The principal investigator in a cooperative agreement between the Forest Service and Vanderbilt University has initiated a study of threatened and endangered vascular plant species within the 13-state Southeastern Area, their habitat requirements and the effects of forest management practices on their survival and recovery. Mr. Nathan A. Byrd, Multiple Use Specialist for the Service and co-investigator, has coordinated the project which was initiated in June of 1975 and which continues in force through December 1976. Current data on threatened and endangered U. S. species are consulted from which are extracted only those with forest affinities and endemic to the southeastern U. S. A. Each species of these last is being checked as to its geographic range, its habitat, and its distinguishing characteristics. A list of pertinent literature is in preparation. Descriptions of the species are being done, these accompanied by how current management practice might influence, adversely or positively, each species.

The basis for a list of forest related species has been the "Report on Endangered and Threatened Plant Species of the United States," (15 December 1964) which was presented to the Congress by the Smithsonian Institution. Supplements to this list, those containing additions and deletions, are also consulted. From this list only forest related southeastern species have been selected, but the extracted list still involves over 200 species in that most of the southeast is or was forested. Inclusion on the project list of some species of open areas (i.e., cedar glades, granite outcrops, shale barrens, heavy earth formations such as the Black Belt) may be open to question; however, in such areas many of the species are seral to forest and in that sense are forest related. An attempt is being made to visit localities for as many of the species as possible within the limitations of project time. This, where possible, allows for the collection of voucher specimens of the species concerned and for the getting up of field notes on habitats and associated species. Where such is not possible, a consultation of specimens already collected together with an appraisal of available published information becomes necessary. During 1975 and early 1976 the bulk of field work has been in the States of Alabama, Florida, Georgia, and Tennessee. During the summer and fall of 1976 some field work in other parts of the southeastern forest area will be done. Visits to larger herbaria for locality information have been made or are planned. The Smithsonian collections have already been consulted; the very large collections of southeastern plants at the Herbarium, University of North Carolina at Chapel Hill, are also to be studied. A list of pertinent literature for each species is being gotten up largely by Mr. Ronald L. Jones, Assistant on the project and graduate student in Botany at Vanderbilt University.

1/ Professor of Botany, Vanderbilt University, Nashville, Tennessee.

Results and Observations

Circa 100 species are now written up in rough form. Most of the remaining should be both visited in the field and/or written up by the fall of 1976. It is becoming increasingly evident that a listing of occurrence of many of the species is largely of historical value only. In the past decade increasingly large amounts of the habitat formerly occupied by endangered species have been badly bitten into by land developers, dam builders, pine monoculturists, row crop or stock farmers, etc. Thus, for example, many of the localities I personally have known and many gotten from older collections or collectors are no more.

A study of the species on my list shows most to belong to one or another of the following broad categories:

1. Plants of high hydroperiod soils, primarily in the bogs, swamps, flatwoods, and low savanna of the Atlantic and Gulf Coastal Plains. Many of the Orchidaceae, all the Sarraceniaceae, Droseraceae, many Cyperaceae, Juncaceae, Xyridaceae on my list belong here. Whether these are drained for agriculture or for pine plantations the result is the same, the plants are destroyed. A great many are also heliophytic and, therefore, even if the land is not drained, but planted or seeded to pine, the crown closure so desirable from the standpoint of pine production shades such plants out. The greatest number of endangered southeastern plant species probably fits in this category. Unfortunately, the same region is also one of the greatest potential for fast production of volumes of pine. I have no doubt that the greatest challenge to finding a compromise between good forest management and threatened species maintenance lies here.

2. Plants of outcrop areas. Most of the endemic succulents, Saxifrages, many composites belong here. Several are seasonal on or in the temporary pools or shallow soil pockets that form on or near the outcrops (Amphianthus, Isoetes, etc.). A few (i.e., Sedum nevii, Neviusia alabamensis) may occur on outcrops in shade, but most are again heliophytes, forest related only in a successional sense. Most are highly substrate specific, appearing on only certain chalks, limestones, shales, granitic rocks, etc., or on the thin soils overlying or adjacent to such. The greatest threat to many of these is through rock quarrying, through land development for human habitation or recreational use (witness the destruction of large parts of Stone Mountain!!) or through their development for low grade pasture (a major hazard).

3. Plants of high Appalachian forest and balds. Many of the most aesthetically pleasing species are here, in what might constitute the most ecologically sensitive situations of all. Several carices, Lilium grayii, Liatris helleri, Solidago spithamea, Prenanthes roanensis, etc., belong here, some confined to but a few summits in the mountains. Fortunately, many are on government land, either part of National Forest or in National or State Parks. Impact is greatest through exploitations for recreational use or through agriculture in the uplands, primarily grazing. Pressure is increasing from campers, backpackers, and vacationers.

4. Plants of sandhills formations or droughty sandy lands. Among such would be those species confined to the deep sands of the longleaf pine-turkey oak type, the sand pine-evergreen scrub type (as was once so well displayed in the Central Highlands province of Florida). The former is widespread through much of the Atlantic and Gulf Coastal Plain, the latter more local in the Coastal Plain, principally in Florida, but with extensions (and slight facies shifts) northward into Georgia and westward into Alabama. Largely poor agriculturally save for local conversion to fruit production (large scale in Florida!!) these have been a silvicultural challenge to the foresters and have been targets for an increased production of pine, this usually involving removal of competitive scrub species, particularly oak, and thus impacting endangered species. In that the pines are usually row planted, habitat alteration in site preparation or later when pine crowns close is such as to eliminate many of the herbs and shrubs. Fire, used as a management tool in maintenance of longleaf pine reproduction, and always a natural factor in the longleaf pine formations is a considerable factor here. Protection from fire permits further conversion of habitat away from suitable situations for many of these endangered species which are part of disclimax.

5. Plants of special soils related to a particular rock substrate. The Black Belt, for example, occupies parts of a large number of counties in Alabama and Mississippi. Much of this was prairie or savanna at the time of white settlement, but their heavy earths have been so converted to pasture and to row crop agriculture that we have little real information today as to what species they contained originally. Succession to forest appears similar to that occurring on the different calcareous rocks of middle Tennessee and northern Alabama, but forest use does not constitute the real threat to what original country remains.

6. Plants of the rich, mixed mesophytic formations, these best displayed in the Appalachian provinces and interior provinces westward. Many of these appear to occupy very narrow niches, are plants of climax forest soils, and are often among the first to fall victim to poor logging practice, either through resultant insolation, serious soil disturbance involving erosion, or through conversion of the forest either to croplands or pasture. Within the past decade, particularly strip mining has become a major problem. Ironically, the sort of forest practice recommended by the professional forester for most hardwoods (namely careful selection or group selection) would impact these species least; however, any plantwise traveler through this beleaguered part of the forest needs no detailed ecological study to conclude that, on much private and state land, such recommendations are seldom applied.

The abovementioned six cateogries represent the habitats occupied by most of the species on my list. The greatest impact, in the case of most, is through any approach toward monoculture, particularly of southern yellow pine. If the heavy equipment employed in site preparation does not destroy the plants outright, the successful establishment of a canopy of pines provides the finishing touch. If site preparation also involves drainage, it takes no great power of observation to conclude that a plant of high hydroperiod soil will die out. It is also obvious that pasturing of forest land be it high or low has the same ultimate effect. If some of our endangered species are weeds, they are very special weeds that tend not to move around much. A stand of them may be gone the year after pasturing.

Final Observations

As I see it, the difficulties in saving endangered plant species are as follows:

1. We appear still to be far behind in our inventory. Much of the information that is being fed into computers is based on older records. I do not believe that many of these records are checked out today, or are inadequately checked out; thus, more effort in the field is needed on the part of many more trained personnel than are presently supported for such work. Talk to anyone today who is trying to do a state flora in the United States. In endangered species work much too much support appears to be given to administration. The way habitat is being wiped out, last year's record may be no good today. Continuing field inventory, as any who have done it know, is time consuming, expensive, but necessary.

2. We have a problem with education, even among our resource technicians. Most resource managers are understandably preoccupied with how to use the land in their charge or ownership profitably. Their jobs, their income depend on this. How is it possible to convince them that "x" number of species of grasses and sedges, or some of our less colorful composites, all of which comprise a challenge even to specialists, can be protected and at the same time allow for profitable land use? How is it possible to train a woods crew to identify plants, to do this at minimum loss to the efficiency of an operation? These questions have occurred to you all; we have little time to find answers.

In regard to my own work, certainly endangered species it seems to me ought to fit into the management plans for forested lands. Their disappearance from much of their former area ought to be one of the more alarming symptoms of land trouble in the country today, a warning that a large part of a system of forests that (without human manipulation) have provided vast revenues is being altered perhaps irreversibly and certainly to the loss of all.

In order to identify the problem, it helps to be able to identify the plants. The showiest species may, in the long run, show us the way. Everyone can identify a pitcher plant, a fly-trap, a ladyslipper. Of course, such plants are for the same reason victims of commercial exploitation. However, it may well work out that, under a blanket of sensible protection offered to the more conspicuous endangered elements, associated endangered species of grasses, sedges, etc., that are difficult for most of us to identify may themselves be protected. Thus, for example, when instructions are given to ease up on a particular pitcherplant habitat, several rare sedges and grasses will also benefit. So we are then face to face with what we all know must be done, namely to preserve some blocks of habitat intact, even if these be "nested" within largely manipulated areas.

What appears to be ahead for a lot of us who are concerned with preservation of endangered plant species is:

a. Further and timely census of existing localities, clarification of identifying characteristics both of the species and their habitats. Making this information available quickly to those who work with the land or shape lard use policy.

b. Improved communication with land managers, coordination such as will lead to realistic incorporation of endangered species into management plans. This (again) has to involve accurate identification of both the species and their special habitat.

c. To explore further the possibility that a more sophisticated management can evolve, tempered as it will be with a better understanding of all parts of terrestrial systems. The fortunes made from the land as we found it are testimony to the fact that it, meaning all of its quirky species, had a place in making that profit. It should follow that this profitability arose through intact, healthy ecological systems, even the smallest parts of which must have significance economically if not aesthetically.

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ENDANGERED SPECIES - QUESTIONS OF SCIENCE, ETHICS AND LAW

J. Frank McCormick[1]

Abstract

Protection of endangered plant species is commonly sought through scientific research which may provide a better understanding of the environmental changes which threaten plant species. Other efforts focus upon the development of an environmental ethic to protect endangered species out of respect for life in all its varied forms. A final recourse is to secure protection of endangered species under law. The argument presented is that ecological research and evolution of an environmental ethic must be pursued, but neither will protect endangered plant species from extinction. Law and law enforcement are presently inadequate but offer the best promise of effective species preservation.

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Species exist as populations. Each species shares a common environment with others and may modify that environment through the influence of biotic structure or products of physiological processes. Species populations interact with one another in the capture, conversion or movement of energy, nutrients and water within complex natural ecosystems. Accordingly, if research on species biology is to be applicable to problems of endangered species, it is imperative that we include analysis of the ecological niche of each species within the context of the total ecosystem.

Endangered species may acquire such status by remaining relatively immutable in a rapidly changing environment. The constant state of flux of the inorganic world has always been a driving force for organic evolution. However, the rate and magnitude of environmental change resulting from recent activities of a single species, Homo sapiens, exceeds the adaptive capacities of most species, most notably Homo sapiens itself. Each species identified as endangered is a symbolic alarm to the ecosystem of which it is a vital component. The cause for alarm is obvious. Actions and forces which alter the environment to a degree that the most sensitive biological components are endangered, in time, must also threaten additional species, interspecific relationships and eventually the entire ecosystem. Too often in an effort to justify proposed projects and also avoid species extinction, endangered species are protected by isolation or transplantation, much as a surgeon would treat for a localized cancer; when in fact the source of endangerment threatens the entire system as does the spread of cancer through the lymphatic system. Effective treatment eliminates the source of infection, purges the environment of contamination and stimulates repair of afflicted components. Unless we resist taking the path of least resistance, and unless we argue protection of the entire habitat, our legacy to future generations will be endangered animals in Zoos and endangered plants in gardens with no natural habitat to which they might return. Like simple surgery, transplantation is an effective deterent to extinction, but only as a last resort.

Extinction like birth and death of individuals is a natural phenomenon, but it is more significant in that beyond a shift in the equilibrium of mortality and natality there is an irretrivable loss of life form. The most significant questions concerning species extinction, like those often associated with death or pregnancy, relate to the cause of the condition as much as to the condition itself. The prescription offered is for biologists to look beyond the symptoms of species health and safety, to become consciously aware of the causes of species being endangered and to become professionally active in an attack upon these causes. The fight takes place in the arenas of science, ethics and law; each of which are at present mutually irrelevant.

In an egocentric society guided by anthropomorphic ethics, it is surprising that only yesterday we came to realize that human health is dependent upon environmental health. How long will it be before we consciously acknowledge the unconscious reality that not only Homo sapiens, not only certain animals, but all species, including plants, are endangered by the consequences of similar stresses, philosophies, policies and actions?

QUESTIONS OF SCIENCE

Endangered species include those unable to acclimate, adjust or adapt at rate compatible with environmental change. Species-environmental relationips are by definition and practice the subject of ecology. Certain defiencies in this young science are in part responsible for the plight of dangered plant species. Illumination of these problems may identify paths progress.

Ecologists appear to be poor teachers. The lessons of ecology are either orly taught or there is an organized resistance to their acceptance. We pear to have been spectacularly unsuccessful in explaining the interdepenncies of plants, animals and man in the world wide operation of the first d second laws of thermodynamics. Biologists must recognize endangered ant species as sensitive components of an endangered system. Research forts which focus on individual plant species apart from their role in the osystem will be only partially rewarding.

A very serious problem is that most biologists do not recognize the istence of plant species as populations. Ecology texts and courses desibe plants as components of "communities", units of landscape structure. imals on the other hand, are acknowledged to exist as "populations" gulated by complex interactions of density dependent and density independnt factors. Plant populations are seldom subjected to the rigorous mographic, experimental and mathmatical analysis which characterize studies animal population dynamics. Noteworthy exceptions include P.B. Cavers (1967), L. Harper (1960), J.M. Hett (1968), J. Pelton (1953), and R.R. Sharitz (1973). e paucity of research on the population dynamics of plants leaves us unnecesrily ignorant of the interactions between plant species and the stresses ich threaten their survival. We are particularly lacking in quantitative formation essential for prediction, which is an important measure of the wer of any science.

The ecological concept of microenvironment recognizes the ultimate subvision of environment to which species are responsive (Platt, 1958). A rollary to this concept is that there are specific stages in the life cycle d specific physiological processes which are orders of magnitude more nsitive than others to environmental stresses. It is imperative that we go yond analysis of species distribution and abundance and identify the life cle stages and life processes most endangered by a changing environment. The mensions of environment are space and time. Our research design must account r variations in the sensitivities of endangered plant species from time to me and place to place.

The dominance of reduction analysis in scientific methodology is yet other unfortunate characteristic of research in species biology. Reduction alysis can reveal specific determinants of population growth, survival and versity. Holistic analysis coupled with the reduction approach can not only entify cause and effect relationships between endangered plant populations d environmental stress, but also the threats of environmental stress to ecies extinction and to the entire ecosystem. Plant populations, common, re or endangered are so much a part of the complex fabric of natural

ecosystems that reductionist research is inadequate. Alfred North Whitehead, in his classic Science and the Modern World (1925), described the aims of education as being not just the presentation of facts, but also illumination of the facts. Reduction analysis can identify the facts, but illumination requires holistic analysis.

Another misgiving of reduction analysis is that it emphasizes biological dissimilarity rather than similarity. Failure to respect the similarities of all life forms has contributed to ethical and legal disregard for the "status" and "standing" of plants. If not ignored, Baldwin's (1949) exciting and classic descriptions of the biochemical similarities of all life forms can temper the unethical legal treatment of plants as being so dissimilar from other life forms that they should be treated as property.

A frequent error is to argue for the protection of endangered species for spurious reasons. For example, a misconception frequently offered as concept is that species diversity is directly related to ecological stability. Perhap the myth was so readily accepted as reality because it is so irresistably attractive. For if species diversity does confer ecological stability, there exists a universally applicable argument for the protection of all species, most immediately those already endangered. Scientific evidence, however, is insufficient to support this hypothesis. There is in fact significant evidenc to the contrary. Because all arguments for protecting endangered species may be challenged, the arguments must be defensible or they will threaten the credibility of the entire effort. At present the diversity-stability concept is an unproven truth. The time will come when the diversity-stability hypothesis will be proven valid, but ecologists have not yet completed their homework. In the meantime valid arguments for the protection of endangered specie can be proposed on other scientific, ethical and legal grounds.

QUESTIONS OF ETHICS

Ethics, according to Leopold (1949), are self acknowledged limitations to freedom in the struggle for existence. Interactions between individuals are governed by social ethics or mores which vary considerably from time to time and place to place. Interactions between individuals and society are governed by the ethics of social institutions. It follows that interactions between individuals and their environment, which includes other species, are to be guided by an environmental ethic. At this time the first stages of an environmental ethic are gasping for breath in an atmosphere of misunderstanding and resistence. The struggle for existence by endangered plant species will not be successful without the continued evolution of an environmental ethic. This evolution began with the acceptance of limitations upon freedom of interaction with other individuals of our own species, at first obviously with others of ones own race, even sex, within the species. Leopold's (1949) reference to the return of Odysseus to ancient Greece is an appropriate example of the slow extension of ethical behavior to others, and only certain others. During his long absence, Odysseus' wife remained faithful to him, an example of a social ethic within the confines of the immediate family. Upon his return Odysseus, with a single rope, hanged a dozen slave girls whom he suspected of being unfaithful. Beyond the immediate family, others of the race and species, but of a singular sex, were treated as property. How far have we come since

lysseus' return? Ethics, the limitation of freedom of personal action, out f concern for the quality of existence of others, has been extended to others f our species, to all races of our species and equally to both sexes of our pecies; or has it? Is the 1973 Endangered Species Act evidence that in the volution of an environmental ethic we have extended our self imposed limitation of action in order to assist other animals species in their struggle for xistence? Or, is it evidence that in the absence of ethical behavior legal estraint is the only protection for endangered species against extinction? s an ecological ethic evolved to include all species out of concern for the uality of existence of life in its varied forms, among which are endangered lant species? If not, how long will it take? In an egocentric society it s taken centuries to develop standards of ethical behavior just within our wn species. How long will it take to adapt an environmental ethic which respects the struggle for existence of all species including endangered plants? nsidering the threats to existence, the slow evolution of an environmental hic will take too long.

The consequences of failure are too serious to depend on the continued volution of an environmental ethic to protect endangered plant species. Somewhat less idealistic goals are to seek a re-definition of plant life as other han "property" and to attain legal "standing" for plants which will provide ndangered species protection under law. While these goals present a significant challenge, there are many reasons it would be even more difficult to ring about the rapid evolution of an environmental ethic. For example, at recent conference on rare and endangered species in The Great Smoky Mountains tional Park, fear was expressed that identification of rare or endangered pecies would stimulate garden lovers, tourists and even scientists to seek t and deplete populations which might otherwise go unnoticed. Will specimens appear in private gardens or on herbarium sheets as trophies and as false estimony to a unique environmental experience? Leopold (1949) describes this rophy mentality in his essay on the Conservation Esthetic. He describes two roups who have, for a long time, been attracted to outdoor and wilderness ecreation. On the one hand there are those who, by experience and observation esthetically desirable natural environments, develop an appreciation and everence for all life forms and the intricate complexity of their interactions. They enter nature searching for a meaning of life and return with a ersonal concept of life and its creator. Others enter the same scenic wilderess convinced by weekly recitation that God is already with them; that the randest trophy, be it fish, fowl or plant, will be testimony to God's guiding and in finding the largest or most rare specimen. In the absence of ethical ehavior, as exemplified by the trophy mentality, law and law enforcement may ecome the only barriers to the extinction of endangered plant species. In our ociety it appears more expedient to pursue justice under law than in the minds f man.

QUESTIONS OF LAW

Law is an instrument of forced behavior necessary when ethical behavior s unattainable. Plant species enjoy little protection under law, including he 1973 Endangered Species Act. Can law, unlike ethics, change soon enough o obviate the need for biologists to run a race with bulldozers in a final rantic effort to save endangered species from extinction? Progress must be

made in the following areas if we are to obtain effective legislation: 1) a re-definition of plants as being under the stewardship of landowners rather than as being possessed as property; 2) attainment of legal "standing" for plants as currently enjoyed by other forms of life and even by some inanimate objects; and 3) more realistic environmental law curricula.

Concepts of ownership and possession change rapidly as evidenced by the emancipation of felons, slaves, and women within a few decades. Emancipation of plants as property may be the final blow ushering the demise of the untenable Baconian philosophy that man has dominion over nature. Garrett Hardin in the preface to Christopher Stone's classic "Should Trees Have Standing" (1974) argues that property is mistakenly treated as a noun instead of a verb, and is accordingly erroneously accepted as a possession. In fact, property exists only in the sense that there are property rights which recognize certain actions may be taken to protect objects against acquisition or mistreatment. In the verbal sense, property is the existence of defenses against uses of objects in contradiction to those uses intended by the steward of record. If the concept of property is modified to include defense against extinction, or if plant species gain the legal standing of other life forms, endangered plant species may enjoy protection under law. Both seem possible in view of the rapidity of changes in concepts of ownership and the narrow (4-3) defeat of Supreme Court Justice Douglas's dissent in the 1972 case of Mineral King vs. Sierra Club. The dissent argued for the legal standing of plants, and it almost passed. A final problem is the inflexible curricula available to those pursuing training in environmental law. Few environmental law curricula include relevant biology, ecology or environmental science courses. Consequently those in a most advantageous position to speak for endangered plant species are inadequately prepared to do so.

In summary, many plant species are endangered because of scientific negligence. The most rigorous scientific techniques available are seldom applied to the analyses of plant populations, the reductionist philosophy emphasises differences rather than similarities of all life-forms, and the holistic philosophy of ecology has not been effectively applied to studies of endangered plant species. An environmental ethic has not yet evolved which protects plant species in their struggle for existence and the trophy mentality of the Conservation Esthetic has not yet been rejected.

In the absence of ethical behavior, law and law enforcement appear to offer the most expedient protection to endangered plant species. The path to progress forks into two trails, both of which must be explored; both of which lead us away from extinction of endangered species. The longer, more difficult, more idealistic trail leads to the development of an environmental ethic compatible with that prescribed by Leopold (1949), Muir (1918), and Santmire (1970). The shorter, less difficult and more realistic path leads to improved ecological research in plant population dynamics; attainment of legal "standing" for plant species, rejection of the concept of plants as property, and improvements in environmental law curricula. In the absence of ethical restraints, legal restraints upon freedom of action should be considered a last resort. The most serious and tragic consequence of our inability to guide our lives and our nation by an environmental ethic is, by the course of law, a continued loss of corporate and personal freedom.

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SPECIES BIOLOGY: DEFINITION, DIRECTION, DATA AND DECISIONS

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Abstract.--Decisions concerning preservation of rare, endangered and threatened species should be based on biologically sound information. The urgency of the situation dictates that a comprehensive system of information collection, storage and retrieval be developed which will promote the collection of comparable information facilitating decisions on species preservation. A model for such a system for Species Biology Studies is discussed which consists of four basic fields of evidence--reproduction, dispersion, establishment and maintenance. Basic high priority questions in each field of evidence are posed and classification for character classes, and characters with selected character states for studies of reproductive biology of endangered species is presented.

INTRODUCTION

"Species biology" is a holistic approach to the understanding of individuals, populations and population systems through the use of evidence from many different fields or disciplines. It involves an understanding of organisms with respect to their structure, function and position with a time reference. Such studies of the biology of a species or other taxonomic rank involve the work of generalists as well as specialists. This work represents, in part, a reversion to the much needed types of studies made by naturalists of the last century but with a fundamental difference--the application of the best concepts, techniques and equipment of today's specialists. Another difference is that we must in the case of rare, endangered or threatened species focus on the common goal of species preservation--rather than just intellectual curiosity.

Our studies must have specific direction and established priorities. Our first priority should be to understand a species to the point that we can make biological and economic decisions concerning this species at a particular site, in a specific community-habitat type, at a given locality. Studies of specific taxa must be conducted as soon as possible which focus on questions which will allow us to make sound decisions at the earliest possible date. Assuming that we have mostly identified the first order of taxa to be preserved, the question which must be answered is: What information must be collected which will give us this necessary level of understanding to preserve or conserve species both now and for the future?

GENERAL SYSTEM

A general model seems necessary for us to relate and develop informational systems and establish priorities as well as to pose basic high priority questions.

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In the organizational model (Figure 1) we have tried to compartmentalize the essential aspects of a species, which should also be applicable to communities or ecosystems, into four major fields of evidence - reproduction, dispersion, establishment and maintenance. Within these four fields of evidence we

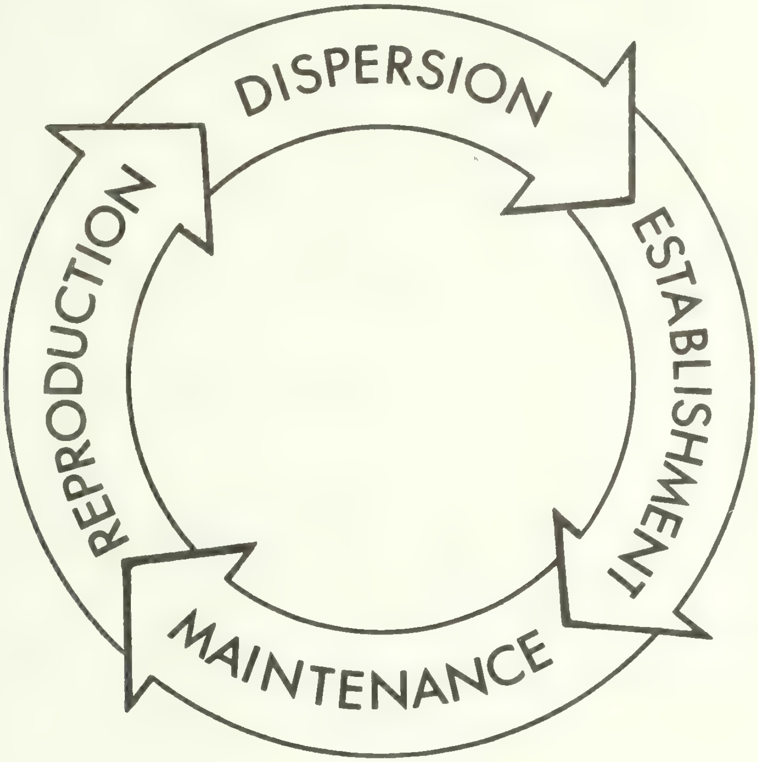

Figure 1. - Fields of evidence for understanding the Species Biology of rare, endangered and threatened plants.

propose two subsystems of information based on priority. To establish priorities we have asked a series of basic questions which seem to require answers early in our species studies which will give us data to make preliminary decisions or assist in guiding further study. Examples of decisions which might be made at this point for a species X are:

1. Species X is indeed endangered, based on field experience, and must be preserved.
2. Species X preservation must include a certain minimal area.
3. Species X preservation depends on the presence of a Species Y.
4. Species X will require habitat management.
5. Species X would best be preserved by the protection of a specific site.
6. Species X is a component of a stable community and little or no management will be required.
7. Species X requires additional study in specific areas before any far-reaching decisions are made.

We propose a preliminary list of questions that species biologists address in each of the four fields of evidence in Priority Class 1. These questions should be answered for each site selected for study and summarized for each species prior to decision-making.

REPRODUCTION	DISPERSION	ESTABLISHMENT	MAINTENANCE
Is the population reproducing?	Are viable propagules present at a site?	Are new individuals present?	Is there a range of age & maturation classes?
What types of reproduction are occurring?	What types of propagules are present?	What is the origin of the new individuals?	What are the age and maturation classes present?
What types of breeding systems are operative?	What is dispersed?	What type of establishment processes are operative?	What is the % of the population in each class?
What types of pollination systems are found?	What are the dispersal agents?	Where is establishment occurring?	What are the spatial relations of the different age-maturation classes?
What is the reproductive potential of the population?	What is the dispersal efficiency?	What is the % of new individuals based on their origin?	What is the survivability of the individuals progressing into the next age class?

REPRODUCTIVE BIOLOGY SYSTEM

The next step seems to be the development of a classification of character classes, characters and character states for each of the fields of evidence which will allow us to systematically collect, store, and retrieve information to answer these questions and formulate others. We have developed such a classification for the field of reproductive biology (including pollination) and are in the process of developing similar classifications for other fields.

The subsystems and character classes for reproduction are given in Table 1. Specific characters and selected character states for the high priority subsystem are given in Table 2.

SUMMARY

The organizational model and classification systems proposed are based on several general assumptions (Table 3) and on the specific assumption that the questions posed are high priority ones and are significant in preservation of rare, endangered and threatened species.

The following examples show the relevance of selected characters from reproductive evidence to decisions on species preservation in general and selection of specific populati^ns or sites.

1. The maintenance of maximum variability with greatest potential for flexibility can best be accomplished by giving protection priority to sexually reproducing populations.

2. The type of breeding system is often a critical factor in determining the size of an area to be protected. To preserve the greatest genetic variability outcrossing species with specific pollen vectors generally will require larger areas than autogamous species or outcrossers with promiscuous pollination.

3. An analysis of pollination systems may indicate that species other than the one being studied also serve as major food sources, nesting sites, etc., for the pollinator of a rare, endangered or threatened species. Preservation of one species is therefore contingent upon preservation of another species.

4. In a series of populations those with high reproductive potential and realization are better candidates for preservation than ones with low potential or realization.

5. In cases where reproductive realization is low, Species Biology Studies may identify causes of this reduction in reproduction which may be corrected to some degree by management practices.

The priority systems should not, however, be misconstrued to mean that only subsystem 1 is important and that the next subsystem can be ignored, or that other questions should not be asked. The answers to questions associated with the first priority group may simply indicate that information from the next priority group or other information is required before any preliminary decisions can be made. The model and character classification scheme are proposed to offer direction and organization for our attack on the problem of understanding and preserving rare, endangered and threatened species.

Table 1.--Classification of pollination-reproductive characters for species biology--subsystems and character classes.

SUBSYSTEM 1: High Priority Information			
I.	Reproductive System	II.	Breeding System
III.	Pollination System	IV.	Reproductive Potential
SUBSYSTEM 2: Second Order Priority			
I.	Phenology (Plant-Vector)	II.	Morphology (Plant-Vector)
III.	Isolating Mechanisms & Reproductive Barriers	IV.	Analysis of Variation & Reproductive Strategies

Table 2.--Character classes, characters and character states for pollination-reproductive biology studies.

SUBSYSTEM 1

A. Reproductive System
   1. Amphimixis
   2. Apomixis
   3. Combination

B. Breeding System (fertilization type based on origin of the pollen)
   1. Autogamy
   2. Allogamy
      a. xenogamy
      b. geitonogamy
   3. Combination (allautogamy)

C. Pollination System (see Radford *et al.*, p. 145)
   1. Type of pollination based on agent
      a. anemophily
      b. melittophily
      c. etc.
   2. Pathway
      a. chasmantheric
      b. cleistantheric
   3. Visitor - Plant relationship (see Faegri & van der Pijl, p. 57 ff)
      a. polytropic
      b. oligotropic
      c. monotropic
      d. dystropic
      e. allotropic (allophilic)
      f. hemitropic (hemiphilic)
      g. eutropic (euphilic)
      h. other
   4. Vector(s)
      a. family
      b. scientific name
      c. vector sex

D. Reproductive Potential
   1. Sex
      a. flower
      b. inflorescence
      c. plant
      d. population
   2. Pollen
      a. No. pollen grains/anther
      b. No. anthers/flower
      c. No. flowers/inflorescence
      d. No. inflorescences/plant
      e. No. pollen grains/plant
      f. No. pollen viability - germination
   3. Seed
      a. No. ovules/fruit
      b. No. fruits/flower
      c. No. possible fruits/plant
      d. No. seed set/fruit
   4. Pollen/ovule ratio
   5. Seed germination
      a. percentage (specify conditions)
      b. phenology (specify conditions)
   6. Reproductive potential through time (plant duration, i.e., length of generation)

Table 3.--General assumptions.

1. Designation of status and legislation will not in themselves preserve rare, endangered and threatened species.

2. Species preservation can best be accomplished through habitat preservation which will involve selection of sites to be protected and/or managed.

3. A tentative list of rare, endangered and threatened species is available.

4. The major goal of Species Biology Studies is to preserve rare, endangered and threatened species through habitat preservation and management.

5. Distributional records and pertinent literature have been checked or reviewed prior to beginning field studies.

6. Field sites for study have been selected and described with precision.

7. Field-laboratory researchers are aware that manipulation at a site or removal of study subjects from a site must be minimal.

8. Field and laboratory studies and monitoring of protected sites will continue after the preliminary studies and tentative decisions have been made.

9. High Priority Type Studies may not be sufficient in all cases and more comprehensive studies may be required.

10. The help of specialists in many fields is solicited and encouraged by those conducting Species Biology Studies.

11. Information relative to management practices is to be assembled and made available to all concerned.

12. Dialogue between interested groups and individuals should be promoted through symposia and conferences on a regular basis and some central agency should make published and unpublished data available to all workers.

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NATURAL AREA CLASSIFICATION SYSTEM: A STANDARDIZATION SCHEME

Albert E. Radford[1/]

Abstract.--Any natural area classification system should include biotic assemblages (vegetation with accompanying fauna), climatic regime(s), soil system(s), geologic formation(s), and land form(s) by physiographic province hierarchically arranged with each entry at each level circumscribed and encoded. The System proposed represents an effort to produce a basic standardization scheme for more efficient and effective inventory and storage and retrieval of information on natural areas, vegetation, floras and rare, endangered and threatened species.

INTRODUCTION

The natural themes for any province: A. Vegetation (with animal dependents), B. Climate, C. Soils, D. Geology, E. Topography are interacting but independent systems that compose the Ecosystem. The basic energy driving the system is sunlight; the basic raw materials are from the intrusive and extrusive magmas, oceans, and atmosphere. Vegetational (with animal dependents) composition, distribution, development is dependent upon climate, soils, geology, topography acting through time. Climate (microclimates) is dependent upon vegetation, soils, geology, topography. Soil composition, distribution and development is dependent upon vegetation, climate geology, topography acting through time. Geological structures, formations, sedimentary rocks are dependent upon climate, vegetation, soils topography and time. Topographic land forms and features, structures and development are dependent upon climate, vegetation, geology, soils and time. All of these interacting, interdependent independent themes and systems form the basis for the natural area classification schemes used in this report.

The ecological natural history themes for any province study or any conservation effort should provide the framework for a comprehensive survey of biotic and abiotic features. All types of communities from the pioneer to the climax developed during time over the different rock types under each significant climatic regime on the major topographic features should be included in the representative site samples of a complete survey of the area. The successional communities, the topo-edaphic climaxes, the continua should be part of the master theme study or conservation effort. Biogenesis has to be integrated with pedogenesis in explaining the present and past development of species and communities; climatogenesis and phylogenesis have to be coupled with succession and soil formation to explain the present composition and distribution of biotic assemblages. In order to understand the origin, migration, evolution of species, floras and faunas as well as the productivity and composition of present communities, man will have to try to conserve the total diversity of species in as broad a range of habitats as possible within the different climates in each province.

SYSTEM

This Natural Area Classification System, based primarily on Vascular Plants, has been designed for inventory and analysis of Natural Areas, Vegetation, Floras and Rare

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and Endangered Species in the eastern United States. This system has been devised to cover (1) all types of successional communities; (2) all types of topo-edaphic climaxes; (3) all vanishing, rare, endangered or relict species, communities and ecosystems; and (4) all disjunct species and communities. The application of a broad natural area classification for any province is necessary for perspective in theme analysis and categorization.

This classification system is based primarily on plant habit (physiognomy) arranged in a time or a successional theme from pioneer annuals to climax angiosperm forests (I-XIV) with upland (I-VII) and lowland (VIII-XIV) toposequences related to moisture (See Table 1). The System based on vegetation physiognomy within a climatic regime and soil order on a major rock formation and landform in a major physiographic province is the first order of the classification. The first suborder, Subsystem, is based on classes of rocks (A-F) or parent materials or water-type. The basic rocks (1) are igneous or metamorphosed igneous; the calcareous (2) are essentially sedimentary carbonate rocks; the carbonaceous (3) are those parent materials high in organic content; the ferruginous (4) are precipitates, sediments or metasediments unusually red and high in iron; the saline rocks (5) are salt or salty; and the siliceous (6) are igneous, sedimentary or metamorphic rocks high in quartz or silicic acid. The rocks are grouped together that produce similar edaphic conditions in a given region.

The second order, Community Classes, are biotic assemblages characteristic of different edaphic conditions within a climatic regime. These classes are relatively broad groups (orders) or assemblages that have been described in the literature over a long period of time. As more inventory experience is gained, the list of classes will be extended. Here the community classes are indicated as monomials, binomials, trinomials, etc. according to the number of strata in the community described. A woody community class with three layers would have each layer described according to its physiognomic composition; e.g. Spruce-fir--Tall herb. The second suborder, Community Subclass, is a combination of specific dominant for the canopy layer and community class for each lower layer; e.g. Red spruce-fraser fir--Tall heath--Low herb or dominant plus habitat; e.g. Pine-savannah.

The basic Community Type (Third order) should be based on quantitative data for a biotic assemblage with a uniform microclimate and edaphic situation (pH, moisture and texture classes should be uniform throughout the area). A one-layered community type would be denoted by a monomial; e.g. *Phragmites communis* (Reed grass community). Stratified (two-layered) communities are indicated by a binomial with the first name based on dominant canopy species and the second on the dominant "subcanopy" species; e.g.,

Community type	Chestnut oak--Low blueberry Canopy dominant Subcanopy dominant (Shrub layer with more cover than herb layer, herbs scattered or essentially absent)
Community class	Oak-hickory forest--Heath

Community type	Buckeye-basswood--Glade fern Canopy codominants "Subcanopy" dominant (Herb layer with more cover than shrub, shrub layer essentially absent)
Community class	Southern Appalachian Hardwoods--Filicalean perennials

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Community type Scirpus americanus--Sagittaria subulata
Emergent dominant Submerged dominant
Community class Cyperaceous perennials--Alismatalean perennials

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Those communities with three distinctive strata would have a trinomial as the community type name; e.g.,

Community type Chestnut oak--Mountain laurel--Galax
Canopy dominant Shrub dominant Herb dominant
(Cover value (5) for each)
Community class Oak-hickory forest--Heath--Diapensialean perennials

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Community type Water tupelo--Duckweed--Coontail
Canopy dominant--Floating dominant--Submerged dominant
Community class Cornalean forest--Lemnaceous herb--Nymphaealean herb

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If the community has four distinctive strata then the community type name would be indicated by the dominant from each of the four layers. If vines occur in two or more layers and have a total cover value of (5), then vine dominant(s) should be part of the community type name following (/) at the end of the binomial; e.g., Chestnut-oak--Low blueberry/Catbrier. Epiphytes with a large cover value should be indicated by (//), then dominant epiphyte name; e.g., Water tupelo-Duckweed--Coontail//Spanish moss.

(Within a "uniform" topo-edaphic and microclimatic situation the habitat is not uniform. The Buckeye-basswood--Glade fern community used as an example above has a few stumps and fallen logs with a distinctive flora (hummophytes), a few seepages with some species restricted to them (crenophytes) and walking fern-covered boulders (petrodophytes). In an inventory of this (or any) community the species should be listed by sub-habitat; e.g. hummophyte, crenophyte, petrodophyte, epiphyte or calciphytes on a calcareous lens or shell sand in a siliceous based community, dry mesophytes over shallow soil in an otherwise mesic habitat, pyrophytes around an old campsite fire, aletophytes on trails through the community etc. within the general community or habitat summary for that particular area or site.)

The Community Subtype (third suborder) would have only the stand dominant indicated, a monomial for two or more layered communities. Eastern Hemlock SAF-23 (See Table 2).

A basic assumption in this classification system is that the animals and lower plant components of these biotic communities will be represented in the vascular plant communities in the diverse habitats.

The first order of the climatic file should include the climatic regimes according to Köppen or some other climatologist. The second order might pertain to temperature, such as the classification of C. Hart Merriam; and the third order should include the edaphic moisture classes as that of the U.S. Department of Agriculture. The soil file should be based on the soil classification system of the U.S. Department of Agriculture with soil order as first order, soil suborder as second order and possibly the soil

type as the third order. The rock file should include the geologic formations as first order; e.g. The Dakota Sandstone, The Morrison Formation; the rock/water classes (Radford and Martin, 1975) as the second order, e.g. basic rock, brackish water; and individual rock types i.e., diabase, hematite and blackish, brown, clear water as the third order.

Under the land forms the first order would include broad features such as basins, beaches, bluffs, hills, plains, lakes with specific types of each as the second order e.g. deltaic-plain, pluvial pool, fault valley; the third order would include the broad habitats such as bottomland field, lake swamp, upland slope etc. (See Radford and Martin, 1975). The province file would be according to Fenneman (1938); e.g. the Appalachian Highlands would be an example of a first order physiographic region, with the Blue Ridge Mountains as an example of a second order province and Pisgah Ridge as a third order subprovince. The individual species, dominants and all others present, in the community type should be listed with the height, duration, growth form, diaspore and fidelity determined for each (see Radford and Martin, 1975). (See Table 2).

CONCLUSIONS

1. Any comprehensive natural area inventory should include the total biotic and habitat diversity.

2. Managed areas of different moisture, pH and texture classes over different parent materials should be conserved within each climatic zone within the province for the perpetuation and study of the native and introduced species, particularly pioneer and transient species.

3. Any standardization scheme for natural area inventories should include vegetational (with faunistic components), climatic, pedologic, geologic, topographic data by province.

4. An acceptable standard natural area inventory system should have each character state properly circumscribed for each entry at each hierarchical level so that future studies and analyses will be comparable and correlative.

5. The Natural Area Classification System should be made as compatible as possible with present classification systems for vegetation, climate, soils, geology, topography and physiographic provinces.

This is an open ended system that can be done as thoroughly as the time and experience of the investigator will permit. The system can be coded for data banking. Natural areas in a conservation system, or those being proposed, should not be continually investigated for the same thing. The information gathered about the region should be made available to subsequent investigators so that new field data resulting from each inventory can be added to the data bank. All taxa should be documented once, not eliminated by eager biologists collecting in each and every visit to an area.

LITERATURE CITED

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Radford, A. E., and D. L. Martin. 1975. Potential ecological natural landmarks: Piedmon Region, eastern United States. Published report for National Park Service.

Table 1

NATURAL AREA CLASSIFICATION SYSTEM SUMMARY

Hierarchical Order: 1. System(S) 1a. Subsystem (SS) 2. Community Class (CC) 2a. Community Subclass (Csc) 3. Community Type (CT) 3a. Community Subtype (Cst)

	SYSTEM(S)	SUBSYSTEMS (SS)
I.	PIONEER HERB	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Pioneer
II.	PERENNIAL FORB	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Forb
III.	GRASS	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Grass
IV.	SCRUB-SHRUB	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Shrub
V.	WOODLAND	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Woodland
VI.	GYMNOSPERM FOREST	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Gymnosperm
VII.	ANGIOSPERM FOREST	A. Basic, B. Calcareous, C. Carbonaceous, D. Ferruginous, E. Saline, F. Siliceous Angiosperm
VIII.	VASCULAR AQUATIC PLANT	A. Fresh water, B. Brackish water, C. Salt water, D. Bog water, E. Calcareous Water Herb
IX.	MARSH HERB	A, Fresh water, B. Brackish, C. Salt, D. Bog, E. Calcareous Marsh Perennial
X.	MARSH GRASS	A. Fresh water B. Brackish, C. Salt, D. Bog, E. Calcareous Marsh Grass
XI.	WET SCRUB-SHRUB	A. Fresh water B. Wet Brackish, C. Wet Salt, D. Bog, E. Wet Calcareous Shrub
XII.	LOW WOODLAND	A. Fresh water B. Wet Brackish, C. Wet Salt, D. Bog, E. Wet Calcareous Woodland
XIII.	LOWLAND GYMNOSPERM FOREST	A. Fresh water B. Wet Brackish, C. Wet Salt, D. Bog, E. Wet Calcareous Gymnosperm
XIV.	LOWLAND ANGIOSPERM FOREST	A. Fresh water B. Wet Brackish, C. Wet Salt, D. Bog, E. Wet Calcareous Angiosperm

GENERAL ORGANIZATION

					MAP UNIT		
(S)	SYSTEM	VEGETATION I-XIV	CLIMATE C-I-IV (temperature)	SOIL ORDER S I-X	ROCK FORMATION R I-*	LAND FORM L I-VIII	PHYSIOGRAPHIC REGION V 1-24
(CC)	COMMUNITY CLASS	ORGANISM ORDER O 1-112	SUBCLIMATE C 1-*	S. SUBORDER S 1-47 (Soil type)	ROCK/WATER CLASS R A - F	TOPOGRAPHIC FEATURE	PHYSIOGRAPHIC PROVINCE 1-24
(CT)	COMMUNITY TYPE	DOMINANT (S) #*	MOISTURE CLASS M a-g	TEXTURE CLASS T a-1	ROCK TYPE R a-r	HABITAT H 1-55	SUBPROVINCE 1- ?
(SP)	SPECIES	INDIVIDUAL #*	HEIGHT A 1-11	DURATION D 1-7	GROWTH FORM G 1-20	DIASPORE F 1-13	FIDELITY F 1-5

(See Appendix D in Radford and Martin (1975) for complete system)

*Classification incomplete

Table 2

COMMUNITY SUBCLASSES (Csc)

A combination of stand, canopy or top layered dominant and community class for each layer below; e.g.

(Csc) Chestnut oak--Ericalean shrub (Heath)
Canopy or stand dominant--Community class for shrub layer
(A mixture of ericad species)

(Csc) Water tupelo--Aralean (Lemnaceous) herb
Canopy dominant — Community class
(A mixture of duckweed species)

COMMUNITY TYPE (CT)

Dominant indicated for each layer or stratum; e.g.

(CT) Chestnut oak--Mountain Laurel--Galax
Canopy Dom. — Shrub Dom. — Herb Dom.

COMMUNITY SUBTYPE (Cst)

Only stand dominant indicated, a monomial for a two or more layered community; e.g.

(Cst) Eastern hemlock SAF-23 (Society of American Foresters numbered stand)
Stand or Community Subtype

(Cst) Balsam fir (SAF-5)
Stand or Community Subtype

CODE APPLICATION OF CLASSIFICATION SYSTEM
FOR COMMUNITY TYPE: CHESTNUT OAK--MOUNTAIN LAUREL

(S)	VII.III.IX.Z.*V.I.
(CC)	23. 2. 2.F.18.6.
(CT)	q26--e6. c. c.p.47.2.
(SP)	q26. 10. 2.20.4.3.
(SP)	e16. 6. 5.3. 2.3

VII,III,IX,Z,V,I;23.Z.Z.F.47.6;q26--e6,c,c,p.b.33.

(S)	Angiosperm Forest Sys. (VII).	Mesothermic (III).	Ultisol (IX).	Unknown (Z)	Ridge (V)		App.Highlands (I)
(CC)	Fagalean Forest (23).	Unknown (Z).	Unknown (Z)	Siliceous angios.	Fault Mountain	(18).	Blue Ridge (6)
(CT)	Chestnut oak--Mountain Laurel (q26-e6).	Dry mesic (c)	Sandy loam (c)	Quartzite (p)	Open slope (47)		Jonas Ridge
(SP)	Chestnut oak (q26).	Large (10)	Summer-green (2)	Tree (20)	Barochore (4).		Fidelity 3
(SP)	Mountain laurel (e6)	Tall (6)	Evergreen (5).	Clumped Shrub	Atelechore (2)		Fidelity 3

*Z = Missing data.

CONFERENCE ON ENDANGERED PLANTS IN THE SOUTHEAST

Summary of the Conference

G. R. Noggle, North Carolina State University

The conference was organized to bring together botanists, foresters, nat-
ralists, and lay persons interested in the conservation and preservation of
ild plants. No attempt was made to develop "lists" of endangered or threatened
pecies; rather the emphasis was on examining the forces and circumstances lead-
ng to the loss and disappearance of plants in various parts of the Southeastern
nited States.

The discussions were grouped under five general topics. Following the
resentation of several prepared papers, comments and remarks from the audience
ere heard.

efinition and Classification of Endangered and Threatened Plant Species

There was general agreement that the definitions developed by the Smith-
onian Institution were satisfactory. Endangered: an endangered species is
ne whose survival is known to be in serious jeopardy. Its peril may result
rom destruction or drastic modification of its specific habitat, over-exploi-
ation by man, disease, predation, or specific competition due to natural succes-
ion. An endangered species must receive protection, or extinction probably
ill follow. Threatened: a threatened species is one that may likely become
ndangered if its habitat is not maintained, or if it is greatly exploited by
an. These often are quite rare and should be monitored continuously. They
ust receive protection.

Dr. James F. Matthews of UNC-C discussed the general philosophy of making
ists (preferably "determinations") of endangered and threatened plant species.
ocal, regional, state and national input is needed and many people must be in-
olved in making appropriate determinations. In North Carolina a primary and
econdary list has been prepared. Following publication of the lists further
hanges will be made. Terms such as "rare," "marginal," "relative abundance,"
exploited," and others were mentioned in the discussions but no attempt was
ade to define them. A forthcoming publication summarizing the proceedings of
Symposium held in September 1974 in Raleigh, N. C., deals with many of these
uestions. The publication Endangered and Threatened Plants and Annuals of
orth Carolina (300 p.) can be obtained ($8.00) from the North Carolina State
useum of Natural History, P. O. Box 27647, Raleigh, N. C. 27611.

ederal and State Legislation on Endangered Plants

Gail Baker of the U. S. Fish & Wildlife Service discussed the Endangered
pecies Act of 1973, a major piece of Federal legislation. This is a strong
ct and can have a significant impact on threatened and endangered plants. One
ection of the Act requires that other Federal agencies and programs must be
eviewed by the Secretary of Commerce or Interior if they bear on the conserva-

tion and maintenance of endangered and threatened species. Another section requires cooperation from the States. Cooperative agreements between States and the Federal Government on land acquisition, management of habitats, etc.,can be established. A model cooperative agreement has been prepared by the U. S. Fish & Wildlife Service and is available on request.

In accordance with section 12 of the Act, the Smithsonian Institution prepared a list of about 3,000 threatened or endangered plants in the U. S. and Hawaii. A list of extinct plants also was prepared. The list was published in Volume 40, No. 127, Tuesday, July 1, 1975, of the Federal Register. Such a publication is the first step in getting the scientific community to comment on the list.

Each state must establish guidelines for cooperating under the Endangered Species Act of 1973. Frank Barrack of the North Carolina Wildlife Resources Commission outlined activities in North Carolina concerning the State Endangered Species Act. Several kinds of activities are involved: development of lists (determinations) of endangered and threatened species; in-depth studies of certain listed species (grants to qualified persons), and development of regulations; land acquisition of selected, critical habitats. At all levels the public must be informed of the work underway. The importance of developing in the public a respect for plants is stressed.

Propagation and Commercial Exploitation of Endangered Plants

Jerry McCollum of the Georgia Department of Natural Resources discussed their approach in establishing regulations to handle exploitation of plants. They are stressing habitat preservation wherein many plants might be protected. A law enforcement activity is being placed in the hands of game wardens. In-service training sessions are being conducted for the game wardens.

Arnold Krochmal of the Southeastern Forest Experiment Station described procedures and techniques being used in propagating and growing some wild plants used for medicinal purposes. More basic information is needed on other plants before they can be brought into cultivation.

Raymond O. Flagg of the Carolina Biological Supply Co., Burlington, N. C., described their activities in collecting and propagating Venus flytrap and other insectivorous plants.

From the discussion that followed these presentations it appears that the survival of many plant species is threatened by indiscriminate collection practices. This kind of destruction by commercial operation can only be stopped by legal constraints on the possession and sale of native plants. Law enforcement will be difficult but it can be done.

Preservation of Endangered Plant Species Through Natural Areas

A major theme throughout the entire conference was the preservation of endangered and threatened plants by establishing natural areas and habitats. The speakers described a number of public (Federal, State) and private (Nature Con-

servancy, Society of American Foresters) efforts to identify and conserve natural areas.

Gary Waggoner, National Park Service, described their activities in identifying natural areas (on the basis of endangered species) worthy of preservation. These areas can be within the National Park or under other ownership. National Landmarks can be recognized on a voluntary basis by private owners.

Gary Henry, U. S. Fish & Wildlife Service, described their role in seeing that the regulations established by the Endangered Species Act of 1973 are complied with. The Fish & Wildlife Service manages about 34 million acres of Federal land in their refuge system. The land is identified as Landmark Areas, Research Areas, and Wilderness Areas. All will have certain components identified as dealing with endangered and threatened species. Federal grants are available to states for the acquisition of wildlife areas.

The Georgia Heritage Program was described by Charles Parrish of the Georgia Department of Natural Resources. A small staff has identified a number of habitats worthy of preservation--some because of endangered plants. To date about 21 thousand acres have been purchased. A major function of the Heritage Program is to acquaint citizens with their historical and biological sites and to develop a social consciousness in harmony with conserving and preserving endangered areas.

Robert Chipley outlined programs of the Nature Conservancy. The programs are structured for habitat preservation. Through a memorandum of agreement with a State they identify endangered and threatened species in various habitats. After such determinations a protection plan is developed.

The Society of American Foresters (Keith Argow) initiated a natural area registration program in 1947. Some 50 natural areas have now been identified in the United States. These are based on forest types.

Research Needs on Endangered Plants

Roy Clarkson, West Virginia University, and Robert Kral, Vanderbilt University, discussed the problems of determining the distribution of plants and their geographical ranges. Regional manuals, monographs, herbarium collections, and journal articles contain much information, but a great deal of field work remains to be done before complete determinations can be made.

Frank McCormick of the University of Tennessee discussed the general philosophy of species preservation. Species exist as populations and must be understood as components of ecosystems. Science, ethics, law, and economics should be pulled together to construct a surface amenable to ecosystem preservation.

James Massey, University of North Carolina at Chapel Hill, set out a framework for understanding species biology and species preservation. Species can be understood in terms of reproduction, dispersal, establishment, and maintenance, all within the ecosystem concept.

As a conclusion to the presentation on species biology, Al Radford, University of North Carolina at Chapel Hill, presented a Natural Area Classification System. The proposed system attempts to describe a basic standardization scheme for more efficient and effective inventory and storage and retrieval of information on natural areas, vegetation, floras and rare, endangered and threatened species.

All of the formal presentations were followed by questions and answers from the approximately 100 persons in attendance. All levels of involvement are essential if an effective program of preservation of endangered and threatened species is to be implemented. "Running along in front of the bulldozer" is important under many situations, and concerned citizens can change the way developers, exploiters, and others view our environment.

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A New Method of Building Scale-Model Houses

by

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Southeastern Forest Experiment Station
Asheville, North Carolina

A New Method of Building Scale-Model Houses

by

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Abstract.--Scale-model houses are used to display new architectural and construction designs. Some soale-model houses will not withstand the abuse of shipping and handling. This report describes how to build a solid-core model house which is rigid, lightweight, and sturdy.

Keywords: Solid-core model.

Scale models are an excellent way to present and convey new housing construction ideas to the general public. If properly constructed, scale models are well worth the time and money spent by architects to display their designs. A three-dimensional model generates more visual interest and enthusiasm than a sketch or line drawing.

The Housing Research Unit of the Forestry Sciences Laboratory in Athens, Georgia, designed several low-cost wood homes to demonstrate efficient utilization of wood in housing construction. The Unit needed to build sturdy scale-model houses to present their designs to the public. Often scale-model houses are weakly constructed and easily damaged in handling. To solve these problems, I built three-dimensional model houses constructed around a solid core of wood, applying simulated siding and trim to the outside (fig. 1).

Figure 1.--Finished scale-model house constructed from a solid core.

The present report shows the steps used to construct solid-core model houses. These instructions can be easily applied to any housing design. The models were built to scale according to the plans found in "Designs for Low-cost Wood Homes," published by the Forest Service.[1]

STEP 1: PLANNING AND MATERIALS

Study the construction plans carefully until you are completely familiar with the design. Decide on the amount of materials needed for construction. I suggest gathering the following materials: scaled balsa wood, water-based stain, latex paint, wood dowel rods, drywall paste, colored paper, contact cement, plywood, poster board, white pine boards, sharp knives, drawing pencils, a T-square, ruler, small compass, C-clamps, polyvinyl acetate (P.V.A.) glue, and a quick-setting model cement. These materials can be purchased at a building supply company or a hobby shop. A plywood cutting board with a 90° angle on the cutting edges is helpful when aligning and cutting straight edges. Be sure to gather a liberal amount of patience before starting construction.

STEP 2: CONSTRUCTING THE SOLID CORE

A solid core is the foundation for a rigid, stable model house. The solid core is formed by laminating white pine boards into a block (fig. 2). Plane the white pine boards to provide a smooth gluing surface. Cut the boards to the approximate block dimensions, leaving an excess for later trimming. Apply P.V.A. glue to the surfaces to be bonded and then stack the boards on top of each other. Place the core block in a cold press or use C-clamps to apply enough pressure to set the glue evenly. Remove any excess glue with a damp cloth. After 2 to 4 hours the block is ready for trimming and squaring.

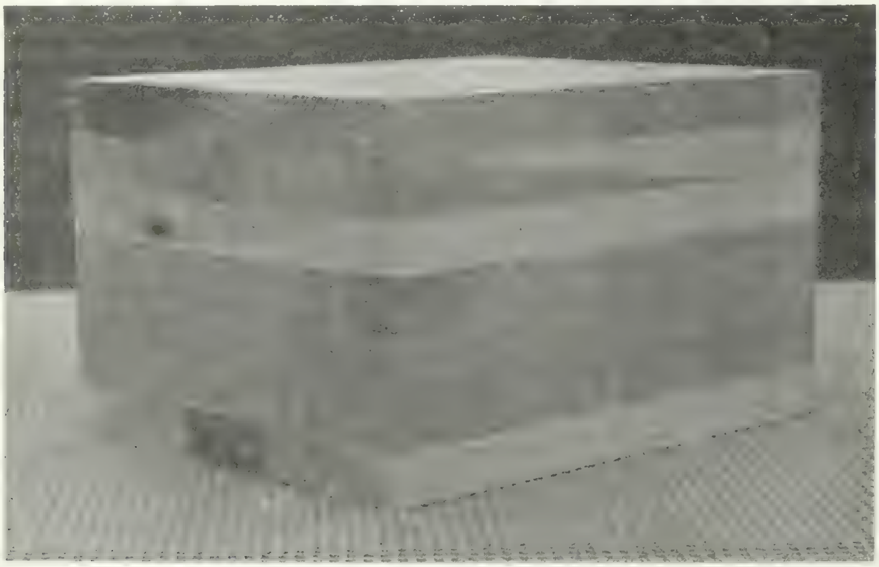

Figure 2.--Laminated block core.

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[1] Anderson, L. O., and Harold F. Zornig. 1969. Designs for low-cost wood homes. p. 1-28. U.S. Gov. Print. Off., Washington, D. C.

Cut the block down to scale size, but leave an excess for later shaping of the roof. Mark the foundation on the bottom of the model core. If your design calls for a raised house on foundation poles, drill holes for the support poles now. When drilling holes in the block, do not penetrate the roof slope. You can reduce the weight of the solid core by drilling additional holes in the bottom (fig. 3). Above all, don't damage any foundation holes when drilling to remove excess weight. For safe operation, use high-speed drill bits in a drill press at medium setting. Mark the angle of the roof and set the bandsaw for desired cuts (fig. 4). After cutting the roof angle the solid core is complete.

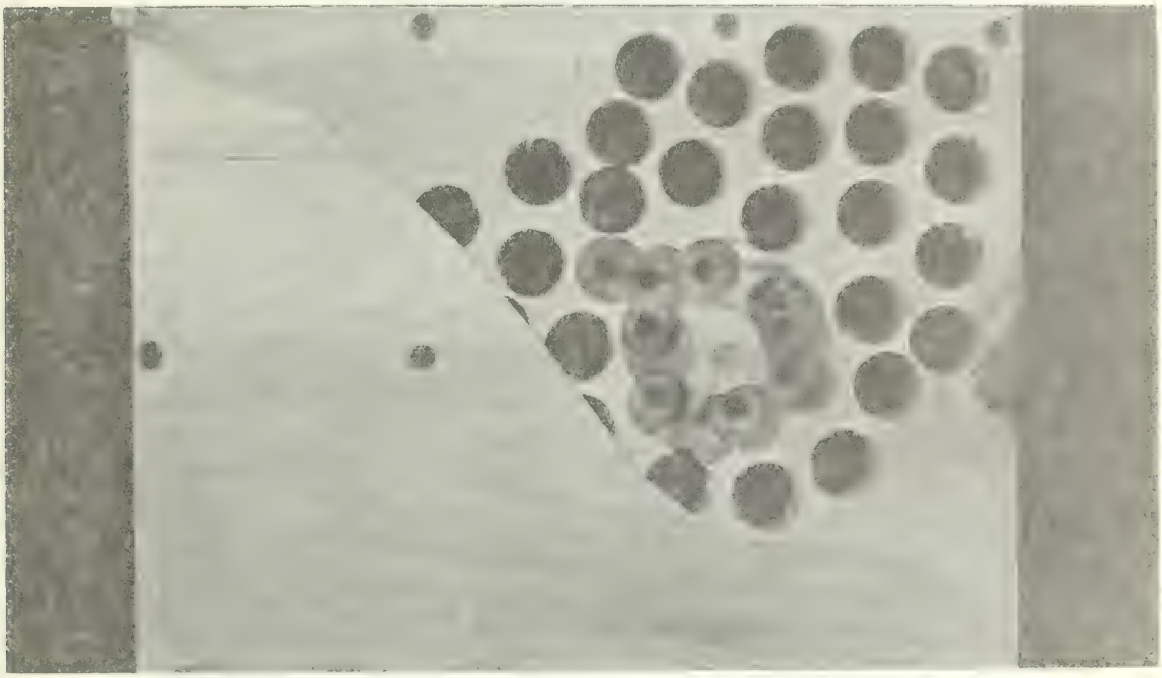

Figure 3.--Holes drilled to reduce excess weight.

Figure 4.--Bandsawing roof slope.

STEP 3: PREPARING EXTERIOR MATERIALS

Window and door casings, window sashes, doors, steps, step stringers, deck flooring and railing, and all siding should be cut to scale from thin balsa wood strips and stained or painted with a water-based stain or latex paint. You must stain before gluing to assure an even surface overall. If you wait until after gluing, the stain will not cover any area that has glue on it. Also, glue does not bond well to oil-based finishes, so water-based finishes are recommended.

After the finish has been properly applied and completely dried, the exterior siding can be cut. First, mark all exterior siding material with soft lead, using dividers to indicate individual lines, creating a design like grooves on 1-11 plywood siding (fig. 5). Then use the plywood cutting board, 30° to 60° or 45° triangles, and a sharp knife. Measure the siding to scale, place it against the fixed 90° angle on the cutting board, and hold the material firmly to score. If more than one piece of the same size is needed, use the first piece you cut as a pattern for all the others. This practice eliminates repeated measurements.

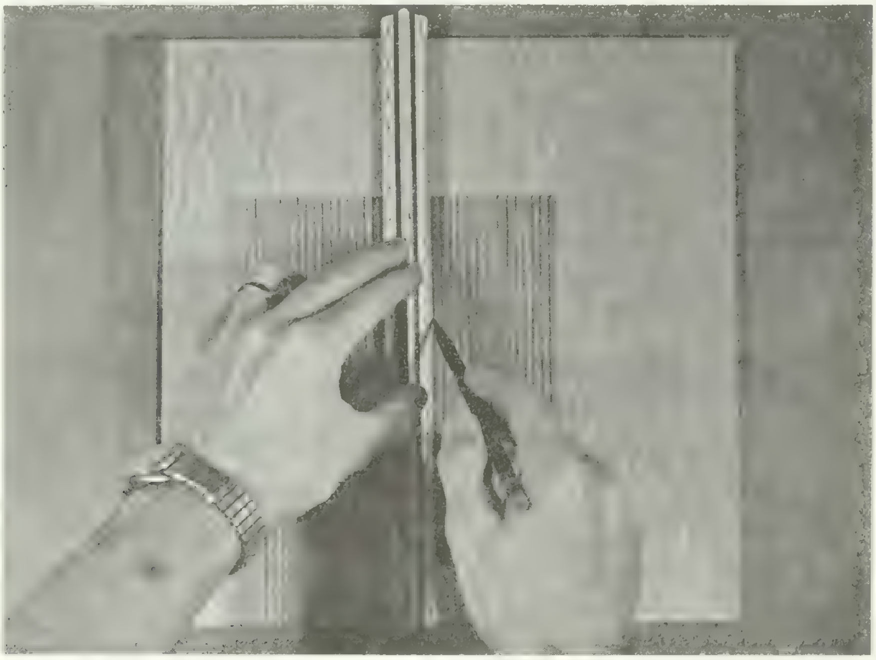

Figure 5. --Marking of exterior material.

STEP 4: BONDING THE SIDING

Arrange all siding on scrap paper with no sides touching and the outside face down. Use an inexpensive paintbrush to apply contact cement to the inside face of the siding and to the outside face of the model core; let the cement dry until tacky. Use contact cement to speed the bonding process. To test when the siding and model core are ready for bonding, press a small scrap of paper to the set surface. If the paper can be removed without sticking, the contact cement is dry and the siding and core are ready to bond. If the paper sticks, the contact cement needs to dry longer.

Bonding is the most crucial point in construction, so be careful and precise. Align the objects accurately before pressing into final position because once together, the objects are bonded! There can be no shifting or separating to straighten or move the siding. One trick is to cut all the outside surface materials oversize and then, after bonding, trim the excess using the model core as a guide. To position the siding, place paper between the surfaces being bonded until they are aligned. Bond one end, remove the paper, and, in a rolling motion, work to the other end pressing the siding to the core (fig. 6).

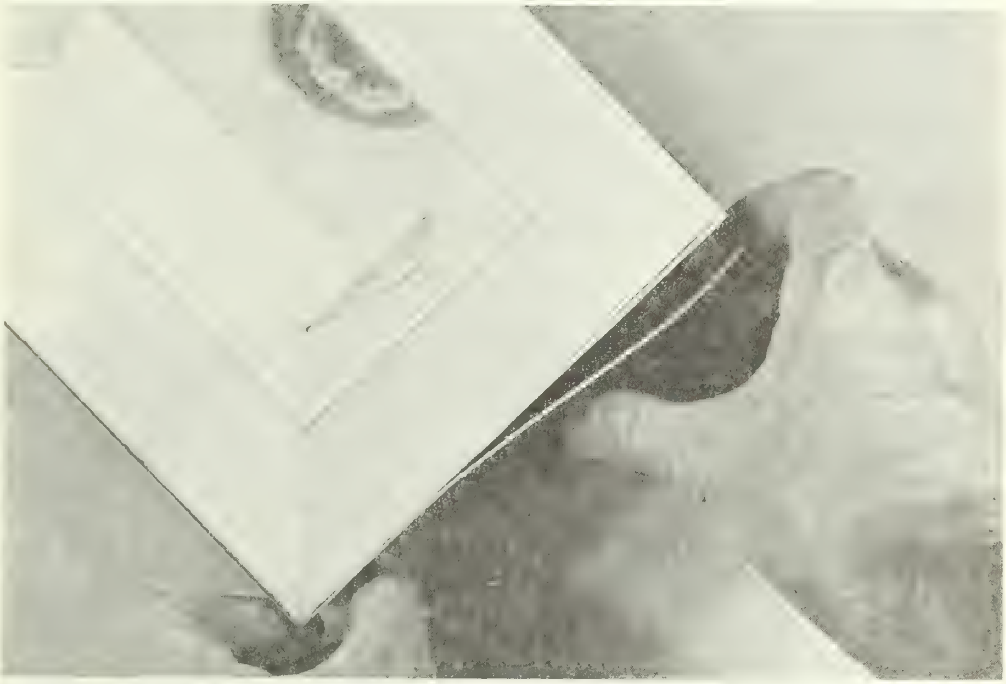

Figure 6.--Bonding siding to core.

STEP 5: FINISHING THE EXTERIOR WALLS

After all the siding has been bonded to the core, you are ready to make the window and door openings. Follow the working drawings and locate the openings. Place a scale or divider in a vertical position at each end of the wall and mark the desired height lightly. Draw very light horizontal lines between the height marks. Then mark width openings on the horizontal lines. Be extremely careful in cutting the openings in the siding (fig. 7). A sharp knife and careful following of the penciled lines are essential.

Use colored paper to represent glass and wood panels. After the paper has been glued in the openings, the jambs, headers, and thresholds should be sized and positioned over the paper. Strips of prestained balsa should be scaled and cut to size for window and door frames, thresholds, and casings. These strips should be thick enough to protrude from the model core so that they are not flush with the siding. For proper bonding, spread contact cement on the bottom and one side of thresholds, jambs, and headers (fig. 8). Remove all excess glue before it dries, to eliminate reflection spots.

Figure 7. --Cutting door and window openings.

Figure 8. --Placing doorjamb in position.

STEP 6: FINISHING THE ROOF

The roof may be covered in several ways. Explained here are two methods: colored poster board and drywall paste. The poster-board construction method requires dividers, a T-square, and a knife. You also need a plywood cutting board with a raised metal 90° angle fixed in one corner to mark and cut the shingle patterns. Cut the poster board to scale, following the blueprint for the shape of the roof and the overhang. Each plane surface of the roof requires a separate piece of poster board. To represent horizontal edges of shingles, draw lines, scaled to the actual shingle size, parallel to the edge of the roof.

Then place the poster board on the plywood cutting board, the outside overhang edge against the horizontal edge of the 90° angle and T-square. Using firm but light pressure, score the poster board, being careful not to cut too deeply. Then position and score the vertical lines representing the shingle width. Bond the poster-board shingle patterns to the core roof with model cement (fig. 9). The overhang will not be bonded to the core; a line should be lightly drawn on the underside of the poster board to indicate the areas to glue. Again, be extremely careful when aligning the roof in its proper position for bonding. When the roofing is bonded correctly, there will be thin spaces between the roof sections, at the hip, valleys, and ridge. These spaces should be covered with thin strips of scored poster board.

Figure 9.--Bonding shingles to roof.

Drywall paste compound can be used to simulate a built-up composition roof or sprayed-on foam roof. First bond the poster board, using contact cement, to all areas to be covered with the roofing compound. This poster board absorbs excess liquid from the drywall compound, preventing any distortion of the model structure. Following directions on the container, mix and spread the joint compound with a spatula. After obtaining the desired buildup, but before the joint compound is dry, use a spatula in a patting motion to give a stippled texture (fig. 10).

STEP 7: CONSTRUCTING THE BASE

To complete and enhance a finished model, build an attractive base from 3/8-inch or 1/2-inch plywood covered with polystyrene foam. The size of the base may vary, but keep the model and base in proper proportion. Bond the plywood and foam together with contact cement. Mark the exact location of the house on the foam base. If the house design requires visible pole foundations, then drill the place for the support poles in the base before finishing the base. The length of the wooden dowels to be used as support poles must be measured carefully, taking into consideration the depths of the holes in the solid core and the base. Follow the blueprint carefully!

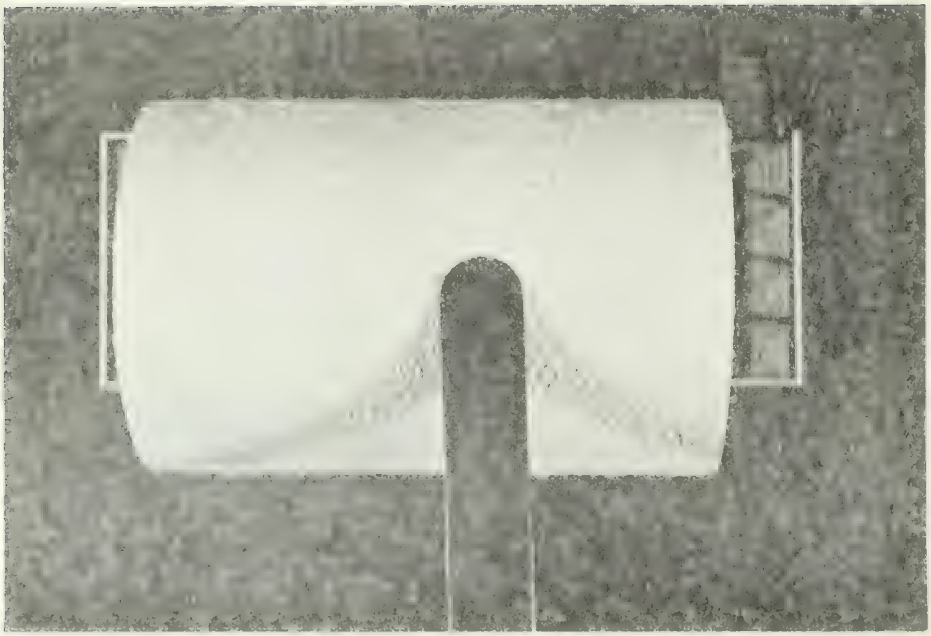

Figure 10.--Spatula used to stipple roof.

Mark the pole foundation positions on the bottom of the base. Drill these positions with a drill press. If a drill press is not available and a hand press is used, drill oversized foundation holes completely through the base. Plumb the precut wooden dowels with a triangle, forming 90° angles between the base and the poles.

The foam is ready to be cut to its desired surface shape. A bandsaw, butcher knife, or other appropriate cutting tool can be used to trim the base. Final shape of the base can be the personal preference of the model builder.

To add texture to the base, cut lines up and down the surface of the foam, 1/8 inch apart and 1/16 inch deep with a sharp knife. Then make similar cuts across the foam, perpendicular to the lines you have just drawn. When you finish, the surface of the foam should resemble graph paper. Scrape the knife over the base to chip away excess foam. When done correctly, this procedure will leave the base with a slightly rough surface (fig. 11). Paint over the rough surface with water-based paints that do not deteriorate plastic foam. Different colored paints can represent earth or grass.

STEP 8: MOUNTING AND FINISHING THE MODEL

After the paint has dried, mount the model onto the proper position on the base or support poles. Securely bond the house and base together with either P.V.A. glue or contact cement. When the glue has set, you may construct outside sundecks, porches, or steps out of balsa wood. Follow the blueprints for the proper scale and position of these exterior options. Use a quick-setting model cement to attach the finished structures to the house. These exterior structures will be the most fragile part of your scale-model house.

Figure 11. --Preparing the base.

Now you have successfully completed a scale-model house (fig. 12). The solid core has added stability and strength to the basic design of model houses. By using your imagination and patience, this method could be applied to a variety of house plans and scale models.

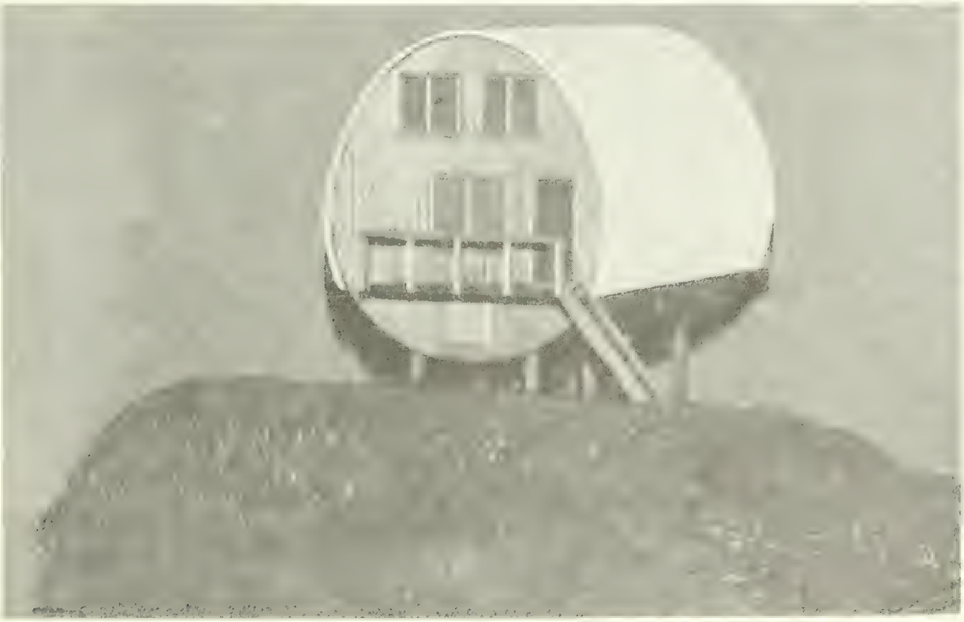

Figure 12. --Completed scale-model house.

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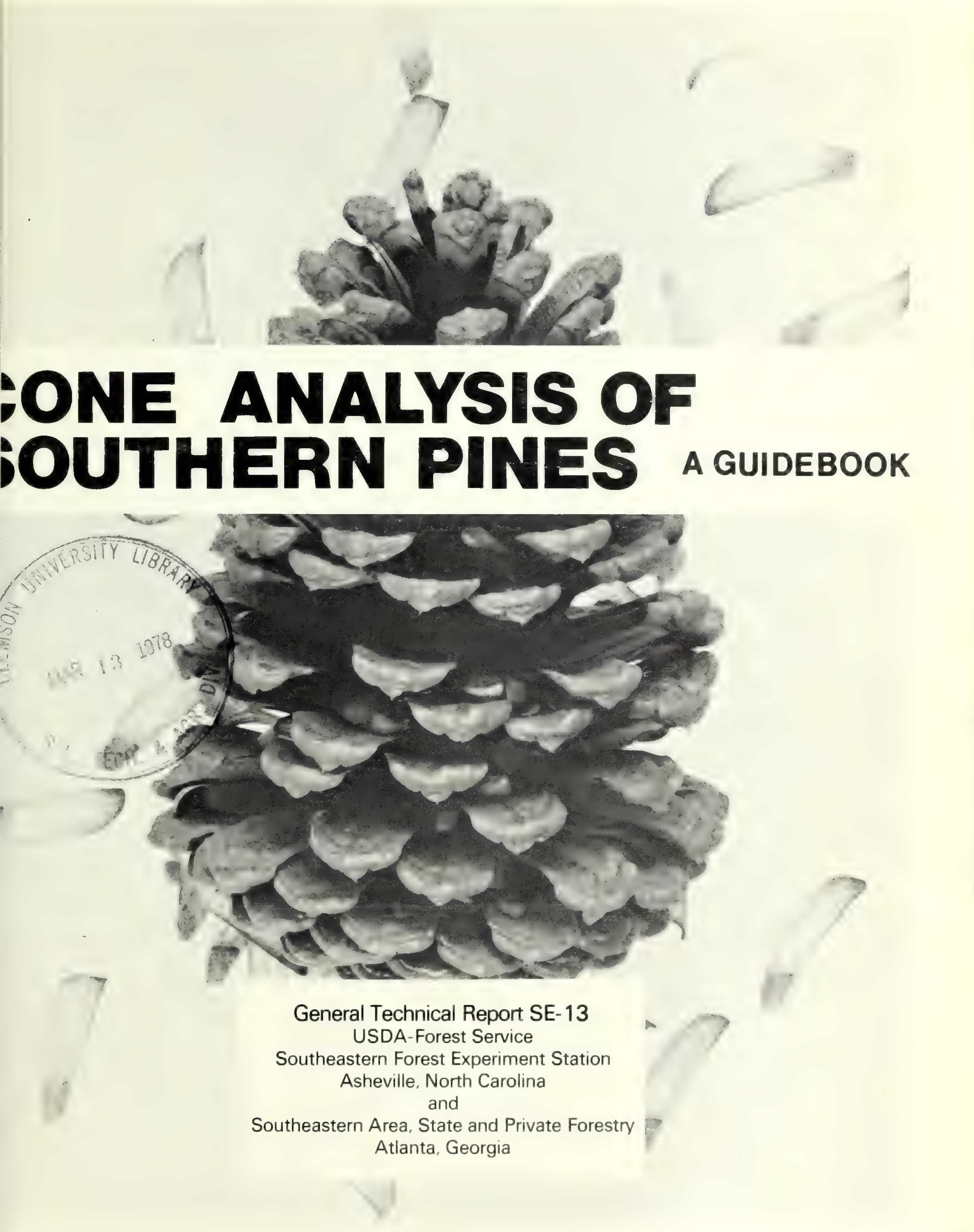

CONE ANALYSIS OF SOUTHERN PINES

A GUIDEBOOK

General Technical Report SE-13
USDA-Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina
and
Southeastern Area, State and Private Forestry
Atlanta, Georgia

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PREFACE

The information in this publication was presented at two Cone Analysis Workshops organized by Dr. Earl W. Belcher, Jr., Director of the Eastern Tree Seed Laboratory, during November 1976 at Macon, Georgia. These workshops were presented by personnel from the Southeastern Area, State and Private Forestry, and the Southeastern Forest Experiment Station. The authors of this workbook are those who developed the workshop and conducted training sessions.

This guidebook contains the information essential for cone analysis and interpretation of the results. Cone Analysis Service (CAS) is also available at cost from the Eastern Tree Seed Laboratory at Macon, Georgia.

CONE ANALYSIS OF SOUTHERN PINES
A Guidebook

by
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INTRODUCTION

Southern pine tree improvement programs require an ample supply of improved **seeds**,[1] but production from southern ne **seed orchards** has often been disappointing. If high production is to be maintained, yields must be monitored and uses of seed losses must be identified. Techniques for determining seed efficiency were first used for red pine, *Pinus sinosa* Ait., by Lyons (**1956**). Bramlett (**1972**b, **1974**) modified and further developed a procedure, known as **cone alysis,** for evaluating production efficiency in southern pine seed orchards.

Cone analysis provides information needed to evaluate seed production and seed orchard management. Actual seed eld of individual **cones** is compared to the potential seed yield. Productivity can then be expressed in terms of seed efiency. One can determine in which stages of seed development certain losses occur, and the types of seed failures can be entified and quantified.

This guidebook outlines the basic cone-analysis procedure, the factors involved in losses of seed, and the interpretation d value of the results. It is a stepwise guide for those who wish to conduct their own cone analyses. More detailed disussions may be found in the publications listed in the Literature Cited section. Tree improvement workers who do not ant to analyze cones themselves can obtain this service at cost from the Eastern Tree Seed Laboratory. This guidebook ill help them understand the analytical results they receive.

erms in boldface type are defined in a glossary at the end of this guidebook

II. CONE AND SEED DEVELOPMENT AND MORPHOLOGY

A basic knowledge of cone and seed development and morphology is essential to understand cone analysis.

Pine trees produce two types of **strobili**: male or pollen-producing **catkins** and female or ovule-producing cones. T primordia of the **female cones** are initiated in the summer. The following spring **female flowers** emerge in an erect po tion from protective bud scales on the tips of new shoots (fig. 1A). The female flowers are composed of many soft, fles scales spirally attached at right angles to a central axis. Pairs of **ovules** originate as small protuberances at the bases scales (fig. 1B). Not all scales produce functional ovules; only those in the central region of the cone have the potential produce ovules and eventually seeds. These are called **fertile scales.** The lower scales and those at the tip of the cone infertile and never bear seeds **(infertile scales).**

At the time of **pollination,** a single layer of cells **(integument)** covers the ovule. Pollination occurs when the **poll grains** are carried by the wind from the male catkins to the female flowers. Pollen grains enter the ovule (fig. 1C) throu an opening (the **micropyle)** in the **seedcoat.** Once in contact with the ovule, pollen grains germinate and **pollen tub** grow from the pollen chamber into the ovule tissue **(nucellus)** (fig. 1D). The pollen tube develops slowly during the f growing season, and the winter is over before it reaches the mature egg cell of the ovule. For more than 1 full year, t ovule remains only a fraction of the size of a fully developed seed. During the year after pollination, the female flowers a called **conelets.**

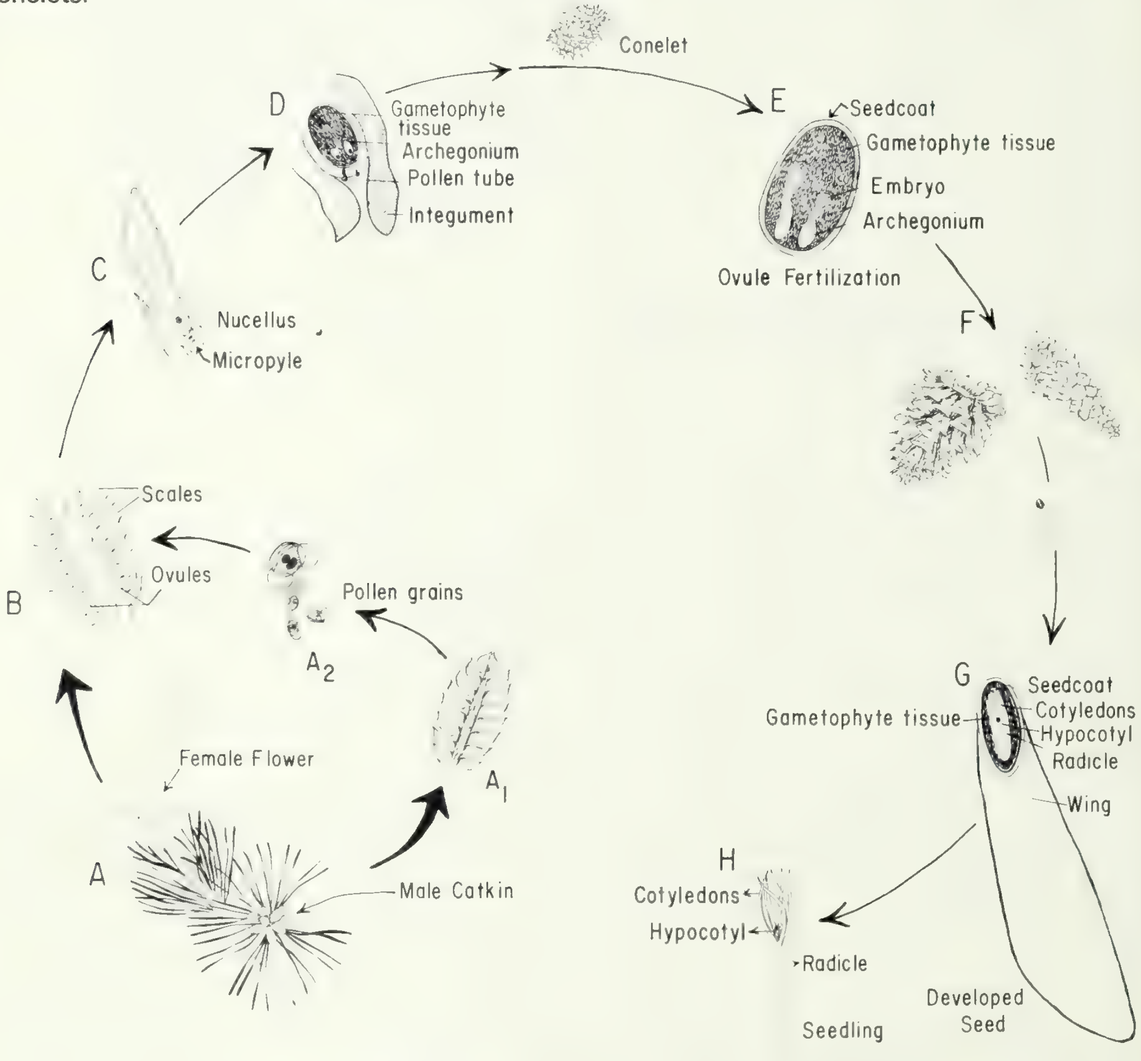
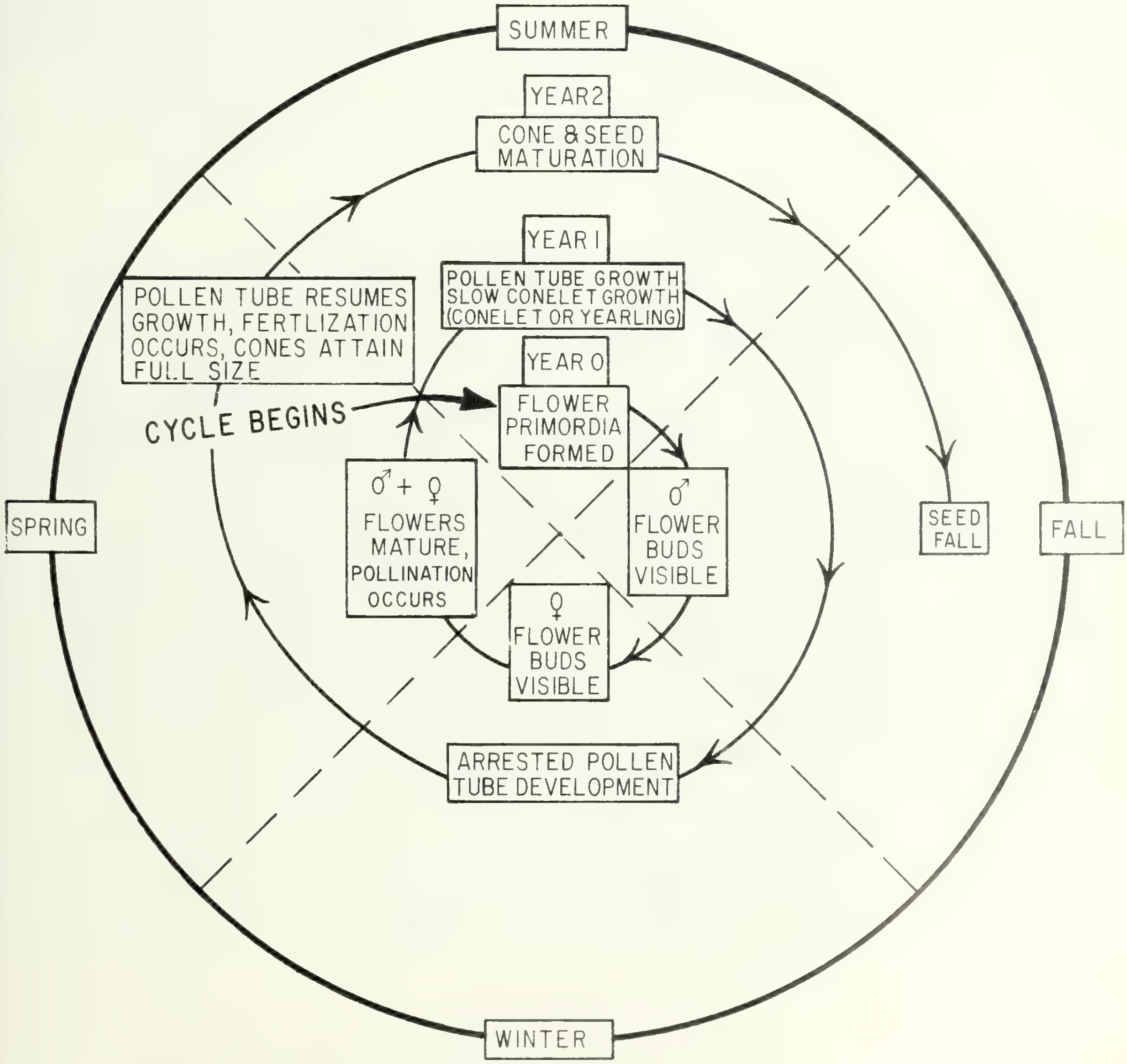


Figure 1.–Pine seed formation. Drawing adapted from one provided by Carolina Biological Supply Company.

ıen vegetative growth starts in the second spring, the ovule also resumes development and enlarges. From 12 to 16 ıs after pollination, depending on pine species, the pollen tubes grow far enough into the ovule to reach specialized ıres **(archegonia)** containing the egg cells (fig. 1E). Sperm cells from the pollen tubes fertilize the eggs, and embryos ssues) form. The gametophyte tissue surrounds the embryo and provides the nutritional reserves for the seed (IN s). During this time, the conelet enlarges rapidly to form a full-sized cone. Seeds are full sized at the time of **ation,** but seeds and cones continue to mature until late summer or early fall.

nature, fully developed seed (fig. 1G) has an embryo composed of immature needles **(cotyledons)**, immature stem **cotyl)**, and an immature root **(radicle)**. The gametophyte tissue enveloping the embryo provides the food reserves for **nation.** The hardened seedcoat protects the seed.

e sequence of pine seed development – from flower primordia formation to seed fall – is illustrated in figure 2. This ɔpment spans parts of three growing seasons.



2.–The cycle for flowering and seed production in southern pines.

III. GENERAL GUIDELINES FOR CONE SELECTION

The method and number of cones to select for analysis depend on the analytical objectives, the planting design, variation within the orchard.

Overall performance of the orchard can be evaluated by selecting cones from throughout the orchard. Exclude all ins damaged cones, but do include cones of all sizes that are normally harvested and extracted. Such a bulk sample can used for comparisons with other orchards or with other years for the same orchard. A sample of from 25 to 100 cones orchard is normally sufficient to evaluate overall seed efficiency. However, with such selection, no conclusions can reached about individual **clones.**

If seed efficiencies must be estimated for individual clones, cones have to be collected separately from specific clo From limited data, it appears that 10 or more cones per clone are required. If individual **ramets** are sampled within a cl then three to five cones per ramet will probably be necessary. Additional research and experience will provide a better b for specific cone sample numbers.

How well the sample represents orchard conditions depends on the variation within the orchard. Morphological tr such as cone length, number of scales, and **seed potential** vary relatively little, and only small samples are required to timate these traits with specified reliability. Seed-yield traits, however, are more difficult to estimate because multiple tors (pollination, insects, etc.) contribute to the variation. Seed and ovule losses must be attributed to specific agents identify problems in orchard management, and such losses can be highly variable. Since seed losses are less w management is good, seed-yield traits can be estimated from relatively small cone samples in a high-yielding, w managed orchard. The very orchards where problems exist and where information needs are greatest are the most diffi to assess and require the largest cone samples.

IV. RECOGNIZING ABORTED OVULES AND SEEDS

In order to understand the details of the cone analysis procedure, it is first necessary to be able to distinguish developed seed from an **aborted ovule.** Ovule abortion may occur during the first or second year of development. Fi and second-year aborted ovules can be distinguished from developed seeds fairly easily by the methods given in t section.

FIRST-YEAR ABORTED OVULES

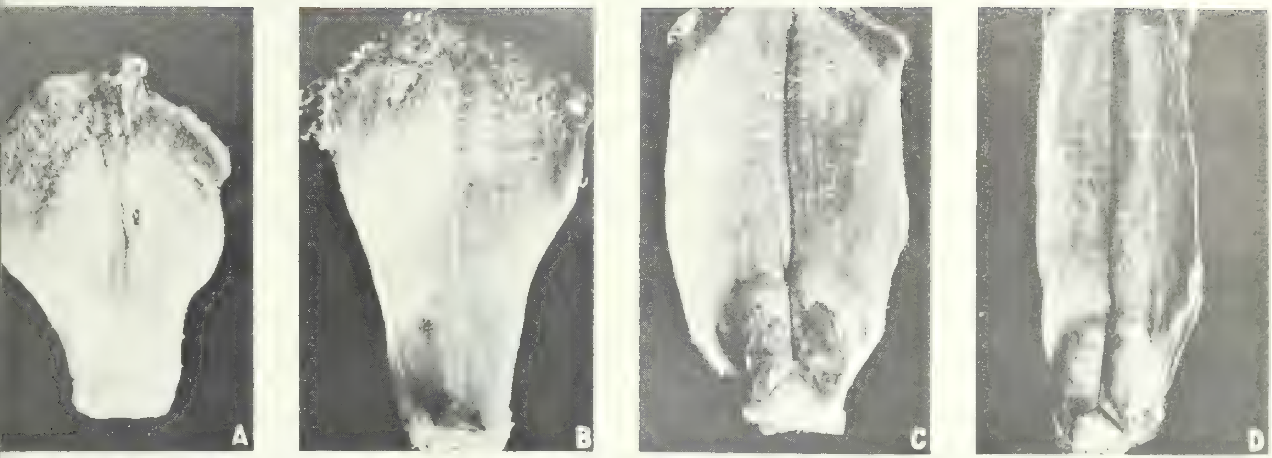
This class of ovule abortion occurs on fertile scales during the conelet stage – before cone enlargement begins in second growing season. The seed wing develops normally, and these ovules have been called "wings without seed Rudimentary, nonfunctional ovules may develop with wings on some of the larger infertile scales. Infertile scales can recognized by their narrow bases (fig. 3). The nonfunctional ovule never has the capacity of becoming a seed and appe as a small dark spot at the base of the wing (Lyons 1956). First-year aborted ovules are noticeably larger than rudiment ovules (figs. 4, 5A and 5B). Some infertile scales at the base of a cone may produce wings with no evidence of eve rudimentary ovule. The smallest infertile scales at the very base of the cone may not produce wings.

SECOND-YEAR ABORTED OVULES

Ovules that abort during the second growing season are always larger than those that abort during the first year. Th may have a partially developed seedcoat (figs. 4B and 5C). These ovules are usually considerably smaller than develop seeds, because they generally abort early in the second year of development. Some ovules abort in late spring or early su mer, these may be as large in outline as fully developed seeds but their seedcoats are collapsed. These ovules are freque tly necrotic or shriveled and usually are attached to the cone scale with resin (fig. 5D).

DEVELOPED SEEDS

Developed seeds are full sized and have complete seedcoats (figs. 3C and D; 4C; 5E, right, and F). These can be plac in specific classes based on their internal appearance on a radiograph (X-ray picture).



3.–Cone scales: (A & B) infertile scales with narrow base and no functional ovules, (C & D) fertile scales containing two
ped seeds with mature seedcoat.

4.–Classification of aborted ovules and developed seeds. (A) first-year aborted ovules, (B) second year aborted ovules, and (C)
ped seeds.

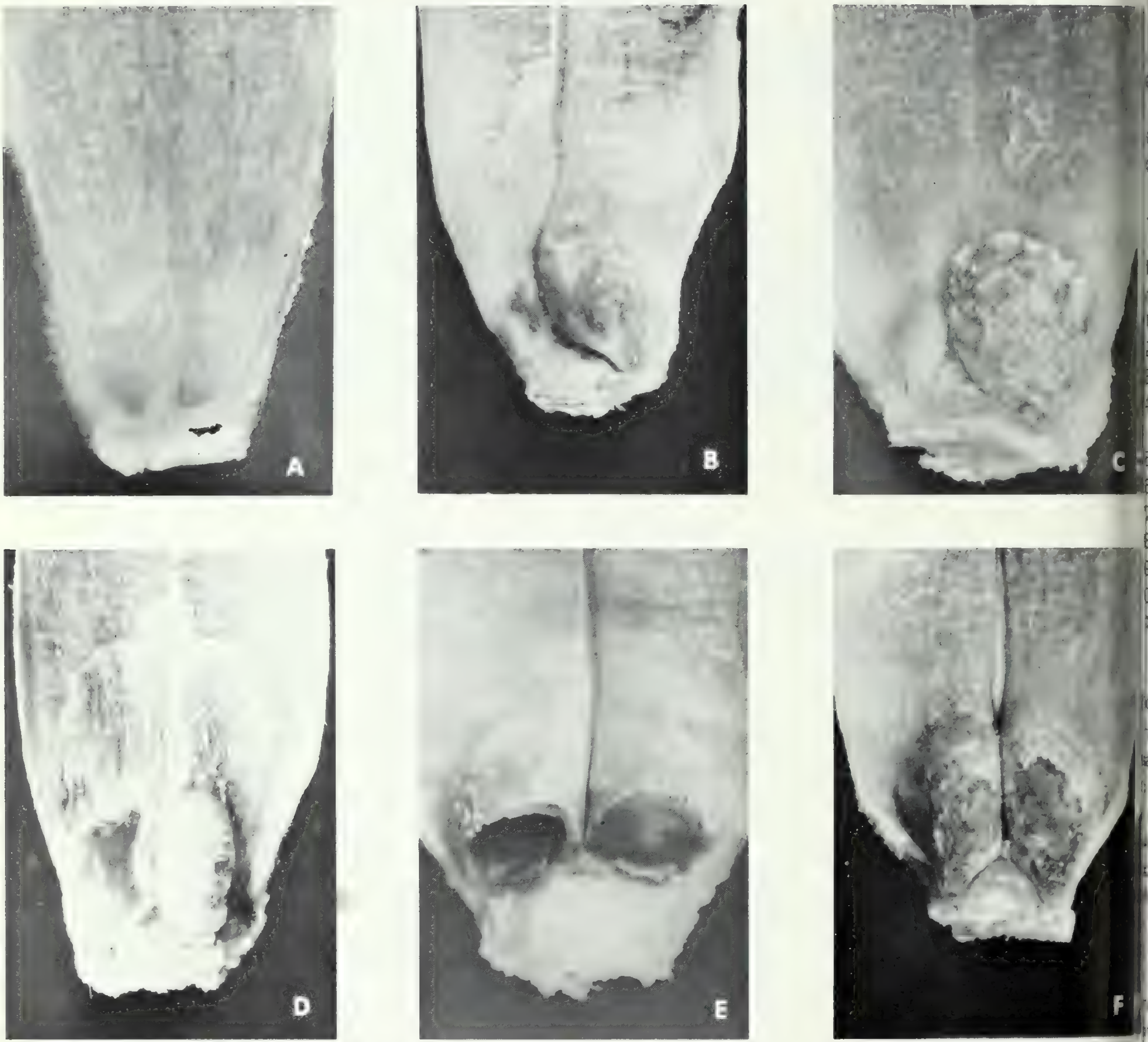


Figure 5.–Classification of ovules and seeds: (A) rudimentary ovules from infertile scale; (B) left, first-year aborted ovule; right, norm ovule; (C) left, early second-year aborted ovule; right, normal ovule; (D) left, typical seedbug induced second-year aborted ovule; rig normal ovule; (E) sliced seed: left, empty seed; right, filled seed; (F) fully developed seeds.

CONE-ANALYSIS PROCEDURE

one analysis, all loose seeds and aborted ovules are extracted from the cone by normal procedures. Then cone scales stematically removed and all the remaining ovules and seeds are collected. The number of scales classed as fertile is used to determine the biological potential of the cone to produce seeds. Ovules and seeds extracted and dissected he cone are then classified by type (figs. 4 and 5). The seed efficiency of each cone is the number of filled seeds as a ntage of the biological potential. The causes for seed losses can be identified and quantified on radiographs. The ex f seed losses to each cause indicates where corrective measures might be taken to reduce seed mortality.

PMENT NEEDS

e analysis requires little specialized equipment. Essential needs are:

- Paper collection bags for individual cones (bag size depends on tree species).
- Cone-drying facility (90°-105° F [32°-40° C] and relative humidity below 50 percent).
- Weighing balance accurate to 1 gram.
- Variable-speed 3/8-inch electric drill mounted in a stationary horizontal position and adjusted to run at the slowest speed.
- Drill bits of various sizes (inches): 1/4, 5/16, 3/8, 7/16, 1/2, 5/8.
- Grafting knife.
- Leather work gloves.
- Metric ruler.
- Containers for soaking cones.
- Germination supplies and equipment.
- X-ray supplies and equipment.

EDURE

e stepwise procedure for cone analysis is presented in a flow chart in figure 6. Bits of data that should be recorded are ted in the chart; the columns mentioned are those on the sample data sheet in the Appendix. Some morphological are considered optional (shaded columns on data sheet) and are not necessary for computation of the most important nd cone characteristics.

o cone-analysis procedures are presented. These are designated "Procedure A" and "Procedure B." During the tion of data, there is one basic difference in the two procedures. With Procedure A, the extracted and dissected oped seeds are combined (steps 9A and 15A – columns 46-61). With Procedure B, the extracted developed seeds 9B – columns 46-61) are kept separate from the dissected developed seeds (step 15B – columns 62-77) from the Each procedure has certain merits and limitations, which are summarized below.

ocedure A. – This procedure evaluates the yield and the extraction and germination efficiencies of all the seeds in the e cone. The developed seeds extracted from the cone by normal procedures are combined with the developed seeds ered by removing the cone scales (dissection). All seeds are then radiographed and classified as described in section e advantage of the procedure is that only a single radiograph is required for each cone. Once the cone analysis is on a particular cone, the extraction, dissection, and seed classification can be completed at one time. Also, the y emphasis is on the number of seeds actually produced in the cone, rather than just on those seeds extracted from ne under laboratory conditions. This procedure is simplest for small organizations doing their own cone analysis. Ger on percentage using Procedure A is based on the ratio of the number of germinated seeds to the total number of eeds produced by the cone.

Procedure B. This is the procedure currently being used by the Eastern Tree Seed Laboratory for its Cone Analysis Se vice (CAS). In this procedure the seeds extracted after forced drying are radiographed, and tests of their germination a begun before the remaining steps in the analysis are completed. Because germination testing is the step that requires t most time, this procedure can substantially reduce the number of weeks needed to complete the analysis. This saving particularly valuable when many cones are to be analyzed.

The germination percentage in Procedure B is the percentage of the extracted filled seeds that produce a normal seed ing. Extraction efficiency by this procedure is the percentage of all filled seeds in the cone that were extracted after dryi (Karrfalt and Belcher 1977).

Before starting cone analysis, the user must decide which procedure to follow. Once a procedure is decided upon, t steps and computations indicated for that procedure must be followed.

Figure 6.–Flow chart for the steps in cone analysis. At several points steps are different for Procedure A than for Procedure

Step 1
Collect a sample of mature, healthy cones to represent the seed orchard or specific clones (see section III).

↓

Step 2
Place each cone in a separate bag with species, year, orchard, clone, ramet and cone identification.
(Record: columns 5-27)

↓

Step 3
Air-dry cones until scale separation begins.

↓

Step 4
Dry cones in forced draft oven or kiln at 90°-105° F (32°-40° C) for 24 hours.

↓

Step 5 (optional)

Estimate and record degree of cone opening. 1 = completely closed; 2 = one-third open; 3 = two-thirds open; 4 = only slightly closed; 5 = completely open. (Record: column 28)

↓

Step 6
Extract loose seeds and aborted ovules by banging cone on counter top.

↓

Step 7

Separate developed seeds from aborted ovules (see section IV).

Step 8

Count and record number of extracted, developed seeds. (Record: columns 43-45)

Step 9A

Place developed seeds in a labeled envelope.

Step 9B

a. Place developed seeds in a labeled envelope for X-ray examination.

b. Radiograph seeds in envelope.

c. Begin germination procedures (see step 18).

d. Classify seed images on radiograph (see section VI). (Record: columns 46-61)

Step 10

Separate first-year aborted ovules from second-year aborted ovules (see section IV). Record only number of second-year aborted ovules. (Record: columns 41-42). Discard all aborted ovules.

Step 11

Soak cone in water until scales close.

Step 12 (optional)

Measure cone length to nearest millimeter. (Record: columns 29-31)

Step 13

Dissect cone: beginning at base of cone, remove lower scales with a knife point (fig. 7). As **cone axis** is exposed, use a drill with bit diameters of 1/4 inch to 5/8 inch to remove cone axis. This facilitates scale removal. Alternate drilling (1 inch or less at a time) and scale removal (fig. 8). Match drill bit diameter with that of the cone axis.

Step 14

Separate scales into groups: (1) lower infertile scales, occurring at the base of the cone (figs. 3A, B and 5A); (2) fertile scales, occurring in the central two-thirds of the cone and having two functional ovules or developed seeds (figs. 3C and D); and (3) upper infertile scales, occurring at the apex of the cone and not having the capacity to produce seed.

Step 15A

a. Take developed seeds from removed cone scales and add to previously extracted seeds in the envelope (step 9A).

b. Radiograph envelope containing seeds.

c. Classify seed images on radiograph (see section VI). (Record: columns 46-61)

Step 15B

a. Take developed seeds from removed cone scales and place in separate envelope.

b. Radiograph envelope containing seeds.

c. Classify seed images on radiograph (see section VI). (Record: columns 62-77)

Step 16

Count any remaining second-year aborted ovules and add to number previously extracted (step 10). (Record: columns 41-42)

Step 17

Determine the number of first-year aborted ovules by subtracting the total number of second-year aborted ovules plus the total number of developed seeds from two times the number of fertile scales on the cone. (Record: columns 38-40)[2]

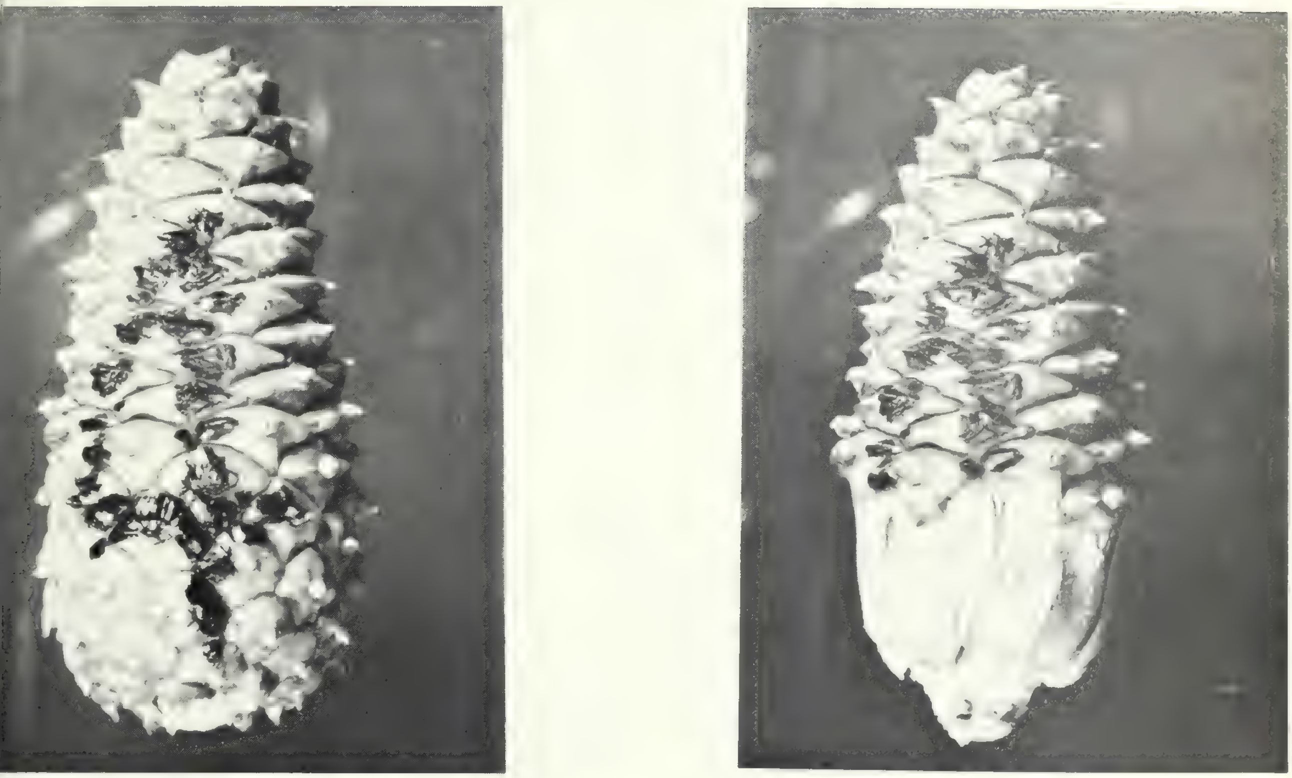
Step 18

Place all developed seeds in germination test using standard germination testing procedures.

Step 19

Summarize data and compute important seed production indicator values (see section VII).

[2] *First-year aborted ovules may be counted as the scales are removed by observing the location of the scale where the seed is produced. Scales w first-year aborted ovules do not have the depression formed in the scale where the seed was located.*



e 7.–(A) Shortleaf pine cone at harvest. (B) Same cone with lower infertile scales removed. Remaining scales are all fertile except few infertile scales at the cone tip.

igure 8.–Cone scale removal. Scale emoval is alternated with drilling out hort distances of the cone axis.

VI. CAUSES OF OVULE AND SEED LOSSES

After first-year aborted ovules and second-year aborted ovules have been separated from developed seeds, the cause for seed losses can be identified. The cause for abortion of an ovule often must be inferred from the time at which abortio occurred. Developed seeds are classified by the appearance of the embryo and gametophyte tissue on a radiograph (fig. 9 Classes of ovules and seeds are defined, and causes for losses are summarized in tabular form in the Appendix.

FIRST-YEAR ABORTED OVULES

There are two causes of ovule abortion in the first year – lack of pollen and seedbug damage.

Lack of viable pollen. – Pollen is an obvious requirement for the production of healthy cones and viable seeds (Sarva 1962). For production of viable seeds, two pollination requirements must be met. Pollen must be available when femal flowers are receptive, and it must germinate and grow into the ovule tissue. Female flower receptivity begins when th opening between the scales is large enough for pollen to enter and extends from a few days to more than a week. Once th scales have closed, additional pollen cannot enter the ovule. If no pollen is present or if the pollen fails to germinate, th ovule aborts early in the first year of cone development (Bramlett and Johnson 1975; McWilliam 1959; Sarvas 1962).

Seedbug feeding. – Feeding by nymphs of the leaffooted pine seedbug, *Leptoglossus corculus* (Say), often causes abor tion of a high percentage of ovules (DeBarr and Kormanik 1975; DeBarr and Ebel 1973; DeBarr and others 1975). Ovule destroyed by seedbugs cannot easily be distinguished from ovules aborting from lack of pollen.

Losses to seedbugs can be estimated by protecting some cones in screened cages and comparing yields of protecte with unprotected cones. With this technique, the impact of seedbugs can be separated from losses to physiological and en vironmental factors.

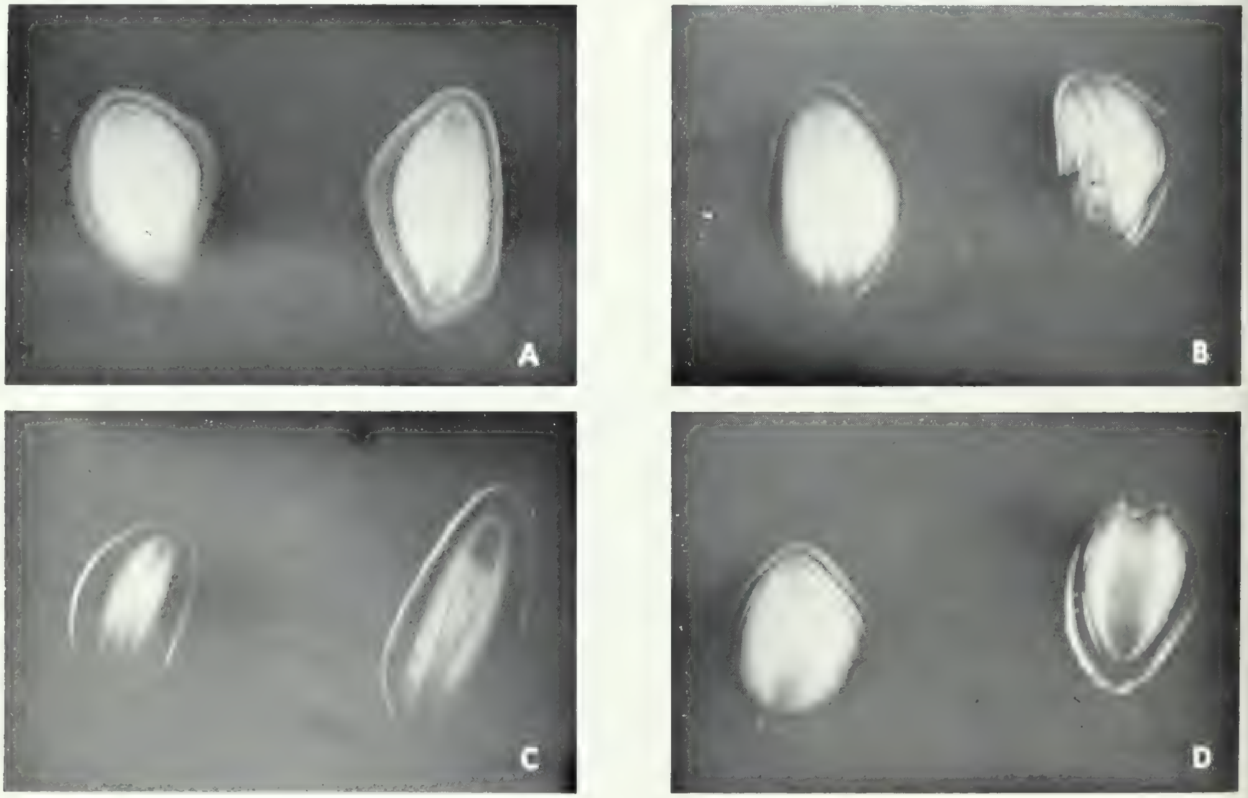
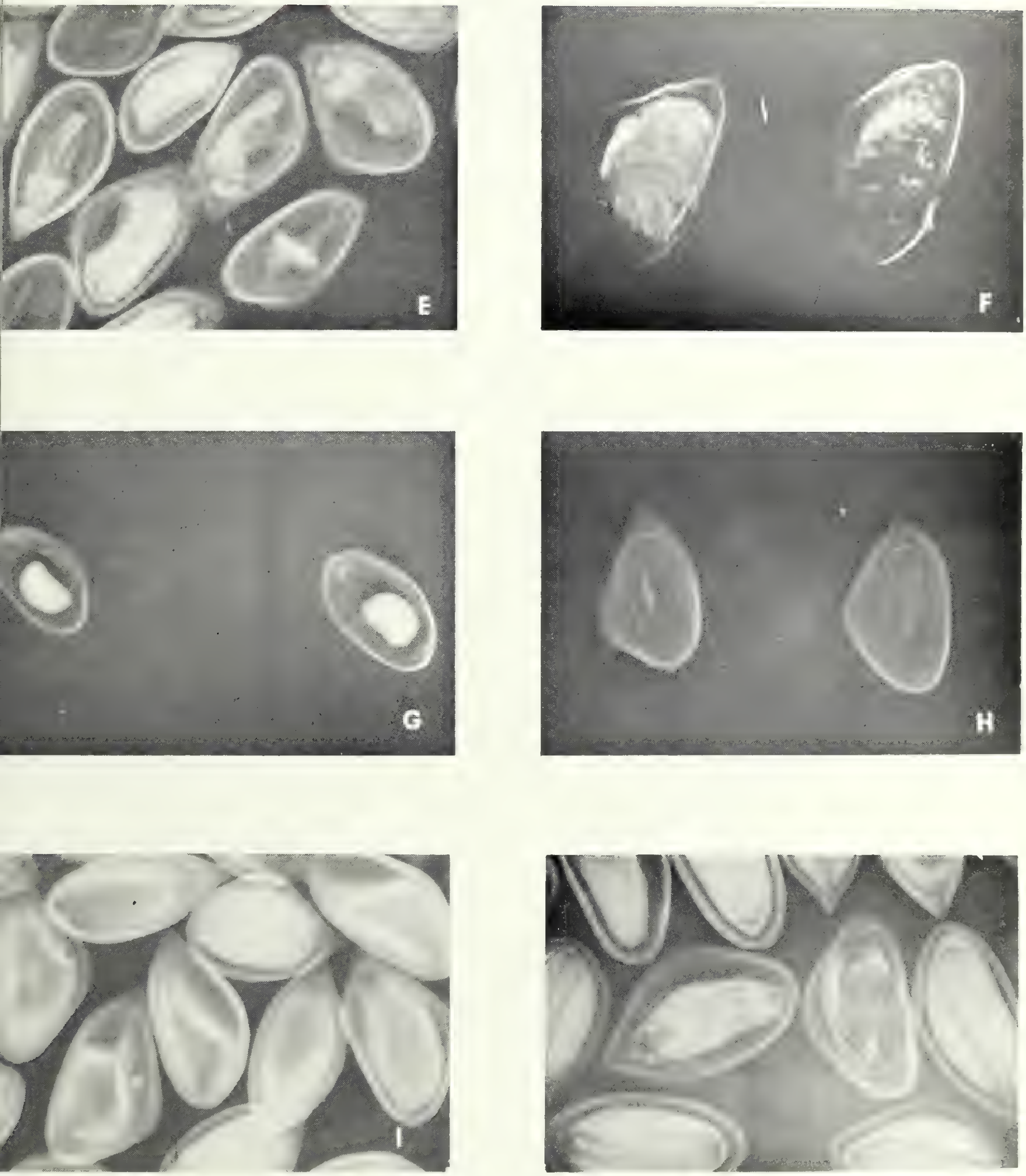


Figure 9 –Classification of radiographic images of developed seeds: (A) filled (potentially sound) seeds; (B) mechanically damage seeds; (C & D) malformed seeds–C, incomplete gametophyte; D, distorted embryo (left); missing embryo (right); (continued)



(continued).–(E) damaged by seedbug; (F) destroyed by seedworm; (G) destroyed by seed chalcid. (H) empty seeds and (I & J)
d by fungi.

SECOND-YEAR ABORTED OVULES

Seedbug feeding. – In extensive studies of shortleaf *(P. echinata* Mill.) and loblolly *(P. taeda* L.) pines (DeBarr 19 slash pine *(P. elliottii* Engelm. var. *elliottii)* (DeBarr and others 1975), and Virginia pine *(P. virginiana* Mill.) (Bramlet Moyer 1973), second-year ovule abortion has clearly been shown to result almost entirely from feeding by the leaffo pine seedbug in early summer (fig. 10). These ovules appear resinous, collapsed, or necrotic on the mature cone s (figs. 4B; 5C, left; and 5D, right).

Developmental problems.–Some ovules stop developing during the second year after they have developed a seed These "miniature seeds" may be only slightly larger than first-year aborted ovules or up to one-half the normal siz seeds of the species. These are all empty. The cause of this type of ovule mortality is unknown, but it apparently re from a block in the normal developmental sequence prior to fertilization. The frequency of second-year aborted ovules to developmental problems has been quite low in production seed orchards.

DEVELOPED SEEDS

Filled, partially filled, and empty developed seeds are readily distinguishable on radiographs. In addition, several typ damage can be identified on radiographs (fig. 9).

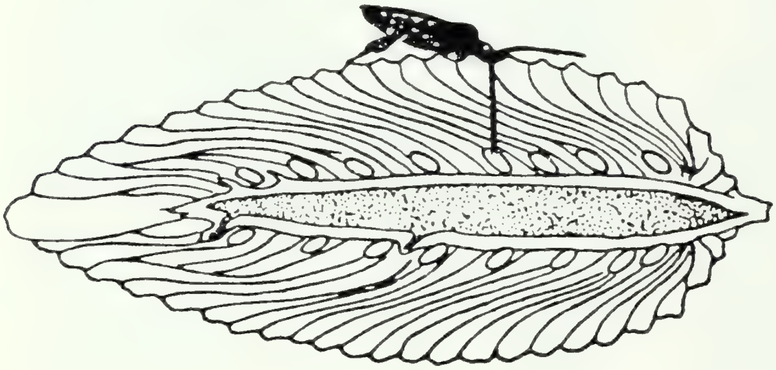


Figure 10.–Diagram of a cone showing how the leaffooted pine seedbug penetrates alternate layers of cone scales and seed wings to puncture seeds lying along the cone axis. (From DeBarr 1970)

Filled Seeds

Filled seeds (potentially sound seeds) are those that have healthy undamaged gametophyte tissue, a normal em and no evidence of insect or fungal damage. These seed structures are readily distinguished on a radiograph (fig. Potentially sound seeds may be mechanically damaged at any stage of extraction (fig. 9B). Since the primary purpo cone analysis is to judge production efficiency in the seed orchards, mechanically damaged seeds should be classe filled.

Partially Filled Seeds

Seedbug.–The leaffooted pine seedbug and the shieldbacked pine seedbug, *Tetyra bipunctata* (H.-S.), feed on sec year cones, damaging and destroying seeds (DeBarr 1967). Damage to fully developed seeds can often be identifie radiographs by the appearance of the gametophyte tissue (DeBarr 1970). Typical seedbug feeding removes irregu shaped portions of gametophyte tissue (fig. 9E). Extended feeding on a single seed often removes most of the gametop tissue and embryo, leaving only a shriveled remnant in the seedcoat.

dworm.–Three species of seedworms, *Laspeyresia* spp., infest seeds of the southern pines (Ebel and others 1975) eedworm-damaged seeds generally are stuck to the cone scales with excrement and silk webbing, most are detec- counted as the individual cone scales are dissected during cone analysis. The few seeds included in the extracted are easily detected on the radiograph (fig. 9F). Seedworm larvae are not present in the seeds, and the exit holes are he gametophyte tissue has been replaced by larvel excrement and boring frass that looks granular on the radiograph en is formed into concentric rings (DeBarr 1970).

d chalcid.–A seed infested by a seed chalcid, *Megastigmus atedius* Walker, lacks gametophyte tissue and contains a arva that is readily visible on the radiograph (fig. 9G). To date, the only pine growing in the Southern United States to be infested by this seed chalcid is eastern white pine *(P. strobus* L.) (Speers 1975).

gi.–Fungal damage is recognizable on radiographs as (1) cloudy or hazy semicircular areas generally at the margin of netophyte tissue (fig. 9I), (2) partial to complete disorganization of both the gametophyte and embryonic tissues (fig d (3) all gametophyte tissue and embryo shrunken or "mummified." Fungal damage may have the same appearance nced seedbug damage on the radiograph. Dissection and close examination of infected seeds have revealed fungi in netophyte tissues, embryo, or both. The mechanisms of fungal penetration are not known, but the presence of fungi s is known to reduce the germination percentage and to increase damping-off of seedlings (Miller 1976).

formed seeds.–Seeds with incomplete embryos, distorted embryos, or incomplete gametophytes are classed as ned. Missing or malformed embryos show up clearly on radiographs (fig. 9C and D). These malformations have ogical causes. In some malformed seeds, the gametophyte tisse does not completely fill the seedcoat and no inter- ect, disease, or mechanical damage is evident (fig. 9C). In these seeds, approximately one-half to three-quarters of mal amount of gametophyte tissue is normally present. Seeds with incomplete gametophytes occur in cones har- before maturity. Malformed seeds occur at a low frequency in most lots and rarely exceed 1 to 2 percent for most

Empty Seeds

ds that contain only a remnant of gametophyte or embryo tissue (fig. 9H) are classed as empty. In the trade, empty n pine seeds are often called "pops." There are two known causes of empty seeds. First, each pine parent carries ecessive lethal genes (Bramlett and Pepper 1974; Franklin 1969). When two recessive lethal genes for the same present, the embryo dies and the gametophyte tissue does not develop. The result is an empty seedcoat with only ant of the dead embryo present. Second, seedbug feeding during the early stages of embryo and gametophyte oment will produce a completely empty seedcoat. The gametophyte tissue is completely destroyed by digestive en- of the insect.

. SUMMARIZING DATA

nterpret the information obtained from the cone analysis, the data must be summarized. The summary should be ed according to trees, clones, or other categories of interest. For the following items, a numerical average can be ted:

Cone opening (CO)	Filled seeds (FL)
Length (LT)	Malformed seeds (MS)
Lower infertile scales (LI)	Seedbug-damaged seeds (SB)

Upper infertile scales (UI)
Fertile scales (FS)
First-year aborted ovules (A1)
Second-year aborted ovules (A2)
Extracted seeds (ES)

Seedworm-destroyed seeds (SW)
Seed chalcid-destroyed seeds (SC)
Fungal-damaged seeds (FN)
Empty seeds (EM)
Germinating number of seeds (GN)

From the basic summary of the raw data, the key indicators of seed performance are calculated as shown below. N bers in parentheses are the columns on the suggested data form in the Appendix.

Indicator **Computation**

1. Seed potential (SP) = 2 x Fertile scales *or* 2 x (34-36)

2. Total developed seeds (TS) = Seedbug-damaged seeds + seedworm-destroyed seeds + se chalcid-destroyed seeds + fungal-damaged seeds + malformed seeds + empty seeds + filled seeds (46-47 and 62-63) + (48-49 and 64-65) + (50-51 and 66-67) + (52-53 and 68-69) + (54-55 and 70-7 + (56-58 and 72-74) + (59-61 and 75-77)

3. Percent developed seeds = $\frac{\text{Total developed seeds}}{\text{Seed potential}} \times 100$ *or* $\frac{\text{TS}}{\text{SP}} \times 100$

4. Percent filled seeds = $\frac{\text{Filled seeds}}{\text{Total developed seeds}} \times 100$ *or* $\frac{\text{(59-61 and 75-77)}}{\text{TS}} \times 100$

5. Percent known insect-damaged seeds =
$$\frac{\text{Seedbug-damaged seeds + seedworm-destroyed seeds + seed chalcid-destroyed seeds}}{\text{Total developed seeds}} \times 100 \textit{ or}$$
$$\frac{\text{(46-47 and 62-63) + (48-49 and 64-65) + (50-51 and 66-67)}}{\text{TS}} \times 100$$

6. Percent malformed seeds = $\frac{\text{Malformed seeds}}{\text{Total developed seeds}} \times 100$ *or* $\frac{\text{(54-55 and 70-71)}}{\text{TS}} \times 100$

7. Percent fungal-damaged seeds = $\frac{\text{Fungal-damaged seeds}}{\text{Total developed seeds}} \times 100$ *or* $\frac{\text{(52-53 and 68-69)}}{\text{TS}} \times 100$

8. Percent first-year aborted ovules = $\frac{\text{First-year aborted ovules}}{\text{Seed potential}} \times 100$ *or* $\frac{\text{(38-40)}}{\text{SP}} \times 100$

9. Percent second-year aborted ovules = $\frac{\text{Second-year aborted ovules}}{\text{Seed potential}} \times 100$ *or* $\frac{\text{(41-42)}}{\text{SP}} \times 100$

10. Seed efficiency (SE) = $\frac{\text{Total filled seeds}}{\text{Seed potential}}$ *or* $\frac{\text{(59-61 and 75-77)}}{\text{SP}} \times 100$

:traction efficiency (EE) =

ocedure A: $\frac{\text{Extracted developed seeds}}{\text{Total developed seeds}}$ *or* $\frac{(43\text{-}45)}{\text{TS}}$ x 100

ocedure B: $\frac{\text{Extracted filled seeds}}{\text{Total filled seeds}}$ *or* $\frac{(59\text{-}61)}{(59\text{-}61 \text{ and } 75\text{-}77)}$ x 100

mination percentage (GP) =

ocedure A: $\frac{\text{Germinated seeds}}{\text{Total filled seeds}}$ x 100 *or* $\frac{(78\text{-}80)}{(59\text{-}61 \text{ and } 75\text{-}77)}$ x 100

ocedure B: $\frac{\text{Germinated seeds}}{\text{Extracted filled seeds}}$ x 100 *or* $\frac{(78\text{-}80)}{(59\text{-}61)}$ x 100

dling efficiency = $\frac{\text{Seed efficiency x Extraction efficiency x Germination percentage}}{10{,}000}$ *or* $\frac{\text{SE x EE x GP}}{10{,}000}$

I. DATA INTERPRETATION AND UTILITY

ourpose of cone analysis is to evaluate seed production and to identify when and why potential seeds are lost. Table s typical values for key indicators in a well-managed seed orchard. It also shows values that may indicate need for ve action.

seed potential defines the biological limit for the number of seeds produced by each cone. Thus, each tree species average seed potential and a range of observed values based upon the number of fertile scales per cone. For exam- seed potential for cones from a slash pine seed orchard averaged 170. Loblolly pines had an average seed potential and Virginia and shortleaf pines had averages of 88 and 87 (Bramlett 1974). Variation in seed potential is relatively vithin specific clones. Seed potentials in a given orchard, however, may differ from the average for the species, ng on the particular clones in the sample.

ted ovules are potential seeds that die before the formation of a normal seedcoat. For all the southern pines, ovule can be a serious cause of low seed yields. The two known causes of first-year aborted ovules (lack of pollen and damage) are influenced by the orchard age. In young orchards, female flowering of many clones usually begins male catkin production is adequate to ensure complete pollination. Unless there is a supply of pollen from sur- g stands, many ovules die within 2 months from lack of viable pollen. In contrast, older seed orchards have an nt pollen supply but also often have large seedbug populations that cause extensive first-year ovule abortion in un- ed conelets. Conclusive separation of insect from pollination problems requires comparison of full seed yields from vith and without screened cages that exclude insects.

nd-year aborted ovules are, for practical purposes, a direct indication of seedbug feeding. Other agents seldom econd-year abortions exceeding 1 to 2 percent of the seed potential. Second-year ovule abortion may reach 50 per- it seedbug control may be warranted when the loss approaches 10 percent of the seed potential. To prevent year ovule abortion, insecticide applications must be timed to reduce populations of leaffooted pine seedbugs dur-

ing the spring when the conelets are rapidly enlarging to full-sized cones. Seedbug feeding on full-sized cones ca empty or damaged seeds rather than aborted ovules.

Total developed seed is simply the number of normal, full-sized seeds in each cone. Obviously, the orchard man strives to maximize developed seed production. With adequate pollination and effective insect control, the developed s yields should approach 80 to 90 percent of the seed potential

Yields of developed seeds are meaningless without considering seed quality. Using radiography, the actual numbe filled seeds per cone is determined. Then seed efficiency is expressed as the ratio of filled to potential seed. Thus, see ficiency measures the productivity of a cone in relation to its biological capacity. The average seed efficiency for a clon an orchard is the single most important measure of seed production. It can be used to compare the relative performanc two pine species with different seed potentials. For example, if a shortleaf pine produces an average of 45 filled seeds of a potential of 90, the seed efficiency would be 50 percent. However, 45 filled seeds in a slash pine cone with a pote of 180 indicates a seed efficiency of only 25 percent.

TABLE 1. – KEY INDICATORS FOR DATA INTERPRETATION

Cone characteristic and threshold level (percent)[1]	Interpretation
1. First-year aborted ovules	
0-10	Good management practice
11-19	Evaluate possible insect or pollination problems
20+	Identify and correct insect or pollination problems
2. Second-year aborted ovules	
0-5	Good management practice
6-9	Evaluate seedbug control program
10+	Increase seedbug control
3. Percent filled seeds	
85+	Good management practice
50-84	Evaluate possible seedbug or inbreeding problems
Below 50	Identify and correct seedbug or inbreeding problems
4. Insect-damaged seeds	
0-10	Good management practice
11-19	Evaluate insect problem and control program
20+	Improve or increase control program
5. Seed efficiency	
55+	Good management practice
35-54	Evaluate causes of seed loss
Below 35	Identify causes of seed loss and begin correction
6. Extraction efficiency	
90+	Good management practice
Below 90	Identify and correct improper conditions or immature cone collections
7. Germination percentage	
90+	Good management practice
80-89	Identify cause (May be: undetected seedbug damage or mishandling of seed)
Below 80	Identify and correct problem (May be: improper germination, undetected seedbug damage, mishandling of seed)
8. Seedling efficiency	
50+	Good management practice
26-49	Identify cause – poor germination, immature cones
Below 25	Identify and correct cause

[1] Each organization may wish to modify these thresholds to meet its targets.

biological maximum for seed efficiency may be as high as 80 percent for individual cones, but values this high are observed under seed-orchard conditions. Seed efficiencies greater than 70 percent have occurred when screen ges were used to protect slash pine cones from insects (DeBarr and others 1975)

d efficiency values of 35 to 54 percent indicate that some potential seeds are being lost. Yields could be increased tifying the specific causes of seed losses and prescribing corrective procedures within economic constraints. Seed cies of less than 35 percent indicate excessive losses. The causes should be identified and the problems corrected as possible.

eloped seeds not classified as "filled" are worthless. Thus, filled seed percentage simply expresses the ratio of filled loped seeds. Filled seed percentages seldom exceed 90 percent in commercial operations, but greater values have eported with controlled pollinations or effective seedbug control (Bramlett and Pepper 1974, Merkel and others Wind-pollinated cones from orchards should average 85 percent or more filled seeds. Lower values indicate losses e or all of the classes identified from the radiographs. Individual-loss classes exceeding 10 percent warrant corrective es.

cts, particularly seedbugs, destroy a large percentage of the developed seeds. In cone analysis, losses are attributed dbugs, seedworms, and seed chalcids. Usually, some seeds classed as "empty" are also the result of seedbug . Therefore, as recognized seedbug losses increase, the number of empty seeds often rises (DeBarr 1974b; DeBarr el 1973).

formed seed losses (incomplete gametophyte tissue, distorted embryo, missing embryo) seldom exceed 10 percent developed seeds in well-managed orchards. Incomplete gametophytes apparently result from retarded development equate nutrition. Cones collected before maturity produce seeds with incomplete gametophytes. Malformed seeds sample lots at such low frequencies that these types of losses are of only minor importance.

gus damage to southern pine seeds has only recently been recognized as a potential problem. The importance of damage is undetermined. Part or all of the seeds from cones with external symptoms of fungal damage may be in- by fungi. Corrective measures are not yet available to prevent seed destruction by fungi.

causes of empty seeds are difficult to identify. Lethal genes in the embryo, seedbugs, and possibly fungi cause seeds. In wind-pollinated seeds from an orchard, as many as 15 percent of the developed seeds may be empty. This vould reflect some effects of self-pollination within the clones in the orchard (Kraus 1975); the proportion of empty s normally high after self-pollination. Lethal genes in embryos cannot be eliminated easily. This genetically controlled minimizes inbreeding and favors outcrossing in pines.

ore than 15 percent of the developed seeds are empty, seedbug damage should be suspected and control programs be reevaluated. Seedbug damage can be reduced with insecticides.

action efficiency measures the ease with which developed seeds are removed from the cones. It is the percentage of ped seeds extracted by kiln or air-drying the cones. It should be noted that this extraction is done in a laboratory - e results are not necessarily the same as would be obtained by commercial extraction. Percentages below 90 in- poor extraction technique or immature cones.

mination percentage measures the viability of seeds classified as "filled" (potentially sound). This value normally es 90 percent or better. Lower germination percentages may indicate improper classification of some seeds in the wan and DeBarr 1974). Germination percentages are useful for comparing the viability of collections from different r from subsequent years.

dling efficiency is simply the product of the three efficiency values – seed efficiency, extraction efficiency, and ger- on percentage. It reflects the total yields of the cone, seed, and seedling crops from the orchard. If any one of the ef- y values is low, the overall efficiency of the orchard is reduced. A maximum realistic goal for production orchards is a g efficiency of about 55 percent. Such would be the case if seed efficiency = 70 percent, extraction efficiency = 90 t, and germination percentage = 90 percent.

e analysis does not estimate all seed losses; it only measures seed losses from surviving cones. Cone losses from ne of flower initiation to cone maturity are not considered. Often 50 percent or more of the seed crop is lost during riod. By combining cone crop life tables with cone analysis, the total seed production for an orchard can be evaluated ger 1975; DeBarr and Barber 1975; Bramlett 1972a; Ebel and Yates 1974).

IX. FOR ADDITIONAL INFORMATION

For help with known insect problems or assistance in identifying insect problems, contact:

STATE FOREST ENTOMOLOGIST

Alabama Forestry Commission
513 Madison Ave.
Montgomery, AL 36104
205/832-5897

Arkansas Forestry Commission
3821 W. Roosevelt Rd.
Little Rock, AR 72204
501/371-1736

Florida Division of Forestry
Collins Building
Tallahassee, FL 32304
904/488-7936

Georgia Forestry Commission
P.O. Box 819
Macon, GA 31202
912/744-3241

Kentucky Division of Forestry
207 Holmes St.
Frankfort, KY 40601
502/564-4496

Louisiana Forestry Commission
P.O. Box 1628
Baton Rouge, LA 70721
504/389-7121

Mississippi Forestry Commission
908 Robert E. Lee Building
Jackson, MS 39201
601/354-7124

N.C. Dep. of Natural Resources
P.O. Box 27687
Raleigh, NC 27611
919/733-4141

Oklahoma Forestry Division
Capitol Building
Oklahoma City, OK 73105
405/521-3886

S.C. State Commission of Forestry
P.O. Box 21707
Columbia, SC 29202
803/758-2261

Tennessee Division of Forestr
2611 West End Ave.
Nashville, TN 37203
615/741-3326

Texas Forest Service
P.O. Box 310
Lufkin, TX 75901
713/632-7761

Virginia Division of Forestry
P.O. Box 3758
Charlottesville, VA 22903
804/977-6555

FOREST INSECT AND DISEASE MANAGEMENT ZONE OFFICE

Forest Insect & Disease Management
Seed Orchard and Nursery Insects
P.O. Box 5895
Asheville, NC 28803
704/258-2850 x625

Forest Insect & Disease Management
Seed Orchard and Nursery Insects
2500 Shreveport Highway
Pineville, LA 71360
318/445-6511

For questions on the use of pesticides, consult:
Pesticide Specialist
Resource Protection
Suite 706
1720 Peachtree Rd., NW
Atlanta, GA 30309
404/881-3734

For further information on cone analysis or on the service supplied, contact:
Eastern Tree Seed Laboratory
P.O. Box 819
Macon, GA 31202
912/744-3311

GLOSSARY

of the definitions given below are based on those in the "Glossary for Forest Tree Improvement Workers" (Snyder 1972) and of Woody Plants in the United States" (USDA Forest Service 1974)

ED OVULE:

-YEAR: Any potential seed that aborts (ceases development) during the first growing season or conelet stage of pine seed iction.

ND-YEAR: Any potential seed that aborts (ceases development) during the second growing season before fertilization or seed hardening

GONIUM: Female sex organ in the ovule of pine.

N: The male strobilus which produces pollen

: Group of genetically identical plants produced by vegetatively propagating a single plant over one or more generations, ac ed by grafting, rooting, air-layering, or tissue culture. Compare ortet, ramet

The female reproductive structure of pines, consisting of a central axis supporting bracts, each of which subtends a scale bear d seeds.

ANALYSIS: A systematic procedure to evaluate the seed production potential and efficiency of pine cones.

AXIS: Central core of the cone.

ET: Immature female cone of pines from time of female "flower" scale closure after pollination until the initiation of rapid ment of the cone a few months before maturity.

EDONS: First leaves developed in the embryo of a seed. They become functional leaves after germination, immature leaves

E CONE: See cone.

E FLOWER: The pine female strobilus (cone) prior to pollination.

E SCALE: A cone scale that is capable of producing seed; generally includes most scales in the upper one-half to two-thirds of

IZATION: The union of the egg (1N) within the ovule and the sperm (1N) from the pollen tube to form the embryo (2N)

SEED (POTENTIALLY SOUND): Mature ovule containing an embryo and nutritive tissue enclosed in layers of protective tissue at); capable under suitable conditions of development into a plant similar to the one that produced it.

TOPHYTE TISSUE: Haploid material (1N) surrounding the embryo; provides nutritional reserves for the seed of pine

NATION: Sufficient development of plant parts from a seed to indicate a potential for developing into a normal plant

COTYL: All of the axis of an embryo or stem of a seedling between the cotyledons and the radicle; an immature stem.

TILE SCALE: A pine cone scale incapable of producing seed; located at the base and apex of the cone.

UMENT: A single layer of tissue enclosing the pine ovule and nucellus. After fertilization, it develops into the seedcoat

PYLE: Small opening in the integument of an ovule through which the pollen grain normally passes to reach the pollen cham-

LUS: Mass of thin-walled cells that composes the central and main part of the body of an ovule, it is surrounded by the integu-

: A female structure which contains an egg cell and develops into a seed.

N GRAIN: The winged male fertilizing structure.

N TUBE: An elongate outgrowth of the germinating pollen grain

IATION: The transfer of pollen to the receptive female flower

TIALLY SOUND SEED: Seed filled with apparently undamaged tissue on which viability has not been tested

LE: Portion of the axis of an embryo from which the root develops; immature root

T: Independent member of a clone.

"In conifers" the structure formed after fertilization; initially consists of seedcoat, embryo, and gametophyte storage tissue

OAT: Protective layer on a seed derived from an integument

ORCHARD: A plantation consisting of clones or seedlings from selected trees and cultured for early and abundant seed ion.

POTENTIAL: Two times the number of fertile cone scales or the maximum number of seeds a cone is capable of producing

ILUS: Male or female fruiting body of pines.

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XII. APPENDIX

CONE ANALYSIS DATA CARD CODING AND COLUMN NUMBERS

ITEM	CODE	COLUMN	
Test number	TN	1-4	Identification Input
Year	YR	5-6	
Species	SP	7-8	
Orchard	OR	9-10	
Clone	CL	11-17	
Ramet	RA	18-25	
Cone number	CN	26-27	
Cone opening	CO	28	Optional Data
Cone length	LT	29-31	
Lower infertile scales	LI	32-33	
Upper infertile scales	UI	37	
Fertile scales	FS	34-36	
First-year aborted ovules	A1	38-40	
Second-year aborted ovules	A2	41-42	
Extracted seeds	ES	43-45	Developed Seeds
Seedbug-damaged seeds	SB	46-47,62-63	
Seedworm-destroyed seeds	SW	48-49,64-65	
Seed chalcid-destroyed seeds	SC	50-51,66-67	
Fungal-damaged seeds	FN	52-53,68-69	
Malformed seeds	MS	54-55,70-71	
Empty seeds	EM	56-58,72-74	
Filled seeds	FL	59-61,75-77	
Germinated seeds	GN	78-80	

	CONE ANALYSIS DATA FORM										SCALES		ABORTED OVULES			PROCEDURE A EXTRACTED & DISSECTED														
																PROCEDURE B-EXTRACTED							PROCEDURE B-DISSECTED							
	TN	YR	SP	OR	CL	RA	CN	CO	LT (MM)	LI	FS	UI	A1	A2	ES	SB	SW	SC	FN	MS	EM	FL	SB	SW	SC	FN	MS	EM	FL	GN
	1 2 3 4	5 6	7 8	9 10	11 12 13 14 15 16 17	18 19 20 21 22 23 24 25	26 27	28	29 30 31	32 33	34 35 36	37	38 39 40	41 42	43 44 45	46 47	48 49	50 51	52 53	54 55	56 57 58	59 60 61	62 63	64 65	66 67	68 69	70 71	72 73 74	75 76 77	78 79 80
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← IDENTIFICATION INPUT → OPTIONAL DATA ← DEVELOPED SEEDS →

CLASSIFICATION OF OVULES AND SEEDS

Class	Columns on data card: Procedure A	Procedure B	Identity[1]	Cause	Comment
A. Aborted ovules					
1. First-Year	38-40	38-40	Small undeveloped ovules with normally developed wing (V)	a. Lack of viable pollen b. Seedbug feeding	Requires caged cones to establish cause
2. Second-Year	41-42	41-42	Flattened seed often resinous (V)	a. Seedbug feeding b. Developmental problems	Usually due to seedbug attack
B. Developed seeds					
1. Filled	59-61	59-61 75-77	Full-sized seed with complete seedcoat (V), embryo, and a gametophyte that fills the seedcoat (R)	--	Includes mechanically damaged filled seed; does not change classification
2. Partially filled					
Seedbug-damaged	46-47	46-47 62-63	Irregular areas of missing gametophyte tissue (R)	Seedbug feeding	--
Fungal-damaged	52-53	52-53 68-69	Cloudy or hazy semicircular areas at margin of gametophyte tissue, disorganization or shrunken or mummified gametophyte tissue (R)	Fungi	--
Malformed	54-55	54-55 70-71	Missing or damaged embryo or gametophyte tissue does not fill seedcoat (R)	Physiological	Early cone harvest will cause incomplete gametophyte tissue
3. Empty					
Seedworm-destroyed	48-49	48-49 64-65	Seed filled with granular material (R) Entry-exit hole in seedcoat (V)	Seedworm feeding	--
Seed chalcid-destroyed	50-51	50-51 66-67	Larva in seedcoat (R)	Seed chalcid feeding	Limited to eastern white pine seed
Empty	56-58	56-58 72-74	Seedcoat empty or containing a shriveled remnant of tissue (R)	a. Seedbug feeding b. Recessive lethal genes	Requires caged cones to establish cause

[1] The designation "V" indicates identifying character visible to unaided eye; "R" indicates visible only on radiograph.

1977

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PROCEEDINGS of the Workshop Management of Southern Forests for Nongame Birds

January 24-26, 1978

Atlanta, Georgia

U.S. Department of Agriculture - Forest Service

Southeastern Forest Experiment Station

Sponsors: Offices of the Forest Service, U.S. Department of Agriculture, in the South—the Southern Region; the Southeastern Area, State and Private Forestry; the Southeastern Forest Experiment Station; and the Southern Forest Experiment Station.

March 1978

Southeastern Forest Experiment Station

Asheville, North Carolina

ABOUT THE COVER:

The sketch, drawn by Dr. Sidney A. Gauthreaux, Department of Zoology, Clemson University, shows the brown-headed nuthatch, which inhabits southern pinelands.

Proceedings of the

Workshop Management of Southern

Forests for Nongame Birds

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Technical Coordinator:

Richard M. DeGraaf
Research Wildlife Biologist,
Northeastern Forest Experiment Station

and

Chairman, National Nongame
Bird Steering Committee

U.S. Department of Agriculture — Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

PREFACE

In May, 1975, a symposium was conducted in Tucson, Arizona,on the management of forest and range habitats for nongame birds. That landmark meeting opened a dialog between avian ecologists and resource managers. It was widely agreed that both groups benefitted each other, and that a series of regional workshops should be held. The objective of the series would be to insure that nongame bird habitat requirements are considered in significant land management practices, and that a diversity of natural biological communities are maintained.

To that end, the National Nongame Bird Steering Committee was formed to sponsor regional workshops to present the state of the art of nongame bird research and management in various ecoregions of the United States. The first workshop in the series was held in Portland, Oregon, February 7-9, 1977, entitled, "Nongame Bird Habitat Management in the Coniferous Forests of the Western United States".

This workshop, "Management of Southern Forests for Nongame Birds", is the second in the series, and presents bird habitat research results and management techniques for all major habitat types in the southern and southeastern United States. This workshop is jointly hosted by the USDA-Forest Service--the Southern Region; Southeastern Area, State and Private Forestry; Southeastern Forest Experiment Station; and the Southern Forest Experiment Station.

The Forest Service was joined by the National Nongame Bird Steering Committee in sponsoring this workshop. Its members include:

Forest Service, USDA
Soil Conservation Service, USDA
Fish and Wildlife Service, USDI
Bureau of Land Management, USDI
National Wildlife Federation
The Wildlife Society
Wildlife Management Institute
National Audubon Society
International Association of Wildlife Conservation Agencies

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Tuesday Morning, January 24

Forest Ecosystem Structure and Function and Effects on Birdlife

Moderator: Fred Kinard
Westvaco Corporation

Keynote Address:

Management of Nongame Wildlife--A Need Whose Time Has Come[1]

Michael D. Zagata[2/]

Aldo Leopold and other early workers in the profession of wildlife management recognized the theoretical value of considering whole communities when making management decisions by coining the often used adage: "As the community goes, so goes the species." However, in practive the needs of game species have generally been the only needs considered or have taken priority. Grange (1949) outlined the wildlife species associated with various successional stages for a white pine climax in Wisconsin. The knowledge that the habitat for great-horned owls would be lost by setting back succession to benefit prairie chickens had little consequence.

Are we, as professional managers, to be faulted for this? Some say yes and some say no. Those who say yes feel that wildlife management should consist of the application of ecological principles that perpetuate a desired diversity. They recognize that wildlife in general has ecological, economic, educational, esthetic, historical, recreational and scientific value to the Nation and its citizens. They feel that emphasis on game species has preempted a consideration of management programs for the nonhunted species.

Those who say no look to the sources of funding for our nation's wildlife management programs, and point out that it is the hunter who has paid the bill. In addition, they stress that game management also indirectly benefits some nongame wildlife.

At this point the meaningful discussions begin to take place with the recognition that any management action benefits some species and adversely impacts others. The formerly familiar blanket statement that "good forest management is good wildlife management" illustrates the folly of a simplistic, single species approach to wildlife management in today's world. We now recognize the importance of treating wildlife and other resources as part of an interrelated system.

It is because of the public's increased knowledge of these interrelationships that we have been prodded into giving greater emphasis to the nongame species. The habitat manipulations we have made for the benefit of game species affected other species directly or indirectly, positively or negatively. Because different wildlife species are of value to different groups in our society, concentration on one species to the detriment of others is likely to, and in fact has, alienate those whose interests have been ignored or negatively impacted.

Because of a greater recognition of the value of all wildlife to mankind by the wildlife professionals and the public, specific legislation to benefit nongame wildlife has been enacted. Examples include the Endangered Species Act, the Marine Mammals Protection Act, and the Wild and Free Roaming Horses and Burros Act. They suffer the same narrow focus as our earlier game programs and are defensive actions. They do, however, serve to point out two important factors: (1) the public is concerned about wildlife for wildlife's sake; and (2) the public can limit the professional's ability to employ sound ecological principles to manage a species, e.g., Wild and Free Roaming Horses and Burros Act. In addition, the Endangered Species Act and Marine Mammal Protection Act have illuminated our lack of basic knowledge about the ecological requirements of most listed species.

The reluctance of the professional to act on behalf of the public has prompted concerned, well-intentioned citizens to draft legislation that would mandate certain actions on behalf of wildlife. On the surface this sounds good to those of us who have fought the upward battle to gain recognition for the value of game, as well as nongame, wildlife. However, there is a real danger in this as was evidenced in a 1976 Senate bill entitled "The National

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[1/]Keynote address at the Workshop on Nongame Birds in Southern Forests, Atlanta, Georgia, January 24-26, 1978.

[2/]Director of Federal Relations, National Audubon Society, 1511 K Street, N.W., Washington, D.C. 20005.

Forest Timber Management Reform Act of 1976" (S. 2926). The bill contained many "carrots" for those concerned with wildlife but could have tied the hands of the professional to exercise his skills.

The factors I have alluded to have set the stage for the title of this talk: "Management of Nongame Wildlife - A Need Whose Time Has Come." In a 1972 survey of households in the southeastern United States, nonconsumptive values of fish and wildlife were found to be greater ($12.3 billion) than combined fishing and hunting values ($11.8 billion). Results of a 1975 survey by the U.S. Fish and Wildlife Service encompassing all 50 states indicated that one-half of those persons 9 years of age and older who participated in nonconsumptive fish and wildlife-related activities also hunted, fished or did both. Membership in the National Audubon Society has grown from 41,000 in 1963 to over 400,000 today. In 1976, Missouri voters passed a referendum for a constitutional amendment to add a one-eighth of one percent sales tax for conservation that is expected to generate about $26 million in 1978 alone. Citizens in Washington, Colorado and New York have also gone on record in support of nongame programs that would include some or all of the following: (1) preserve vulnerable species; (2) establish wildlife observation areas; (3) inventory wildlife; (4) provide for management; (5) develop wildlife education material.

What I am saying is that there is a very solid base of support for nongame management and that the professional community should take the lead and not have to be pushed into converting that support into a program for the management of wildlife by considering whole communities. The message is clear; if we don't, it will happen in spite of us. As professionals, we can not allow that to happen.

Because of the wave of public interest in wildlife, Congress has provided the mandate, or as I view it the opportunity, to make major strides in our knowledge of wildlife, game and nongame alike. The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), The National Forest Management Act of 1976, and the Land and Water Resources Act of 1977 afford us great opportunity to assess our fish and wildlife resource. Such an assessment, combined with greater knowledge of community associations, will permit us to base management decisions on sound data and expand our knowledge of the impacts to be expected from man-induced or natural environmental pertubations. Those of you familiar with the RPA process know, however, that we are a long way from having the necessary wildlife data to make the kind of decisions an ever-increasing segment of the public is asking us to make.

From a selfish standpoint, we can look to the increased funding and personnel ceilings that have and will accompany this increased interest in and concern for wildlife. All that glitters is not gold, however, because the scope of our task will probably increase at a greater rate than the resources needed to do the job. There are 3,699 vertebrate species in the United States and an average of 748 species in each state. An average of 125 species per state may now be taken legally at prescribed places and times for commercial, control and recreational purposes. A survey by the U.S. Fish and Wildlife Service showed that the states want to give attention to an average of 279 fish and wildlife species in each state. It is clear that traditional funding sources are not adequate to do the job if we are going to be aggressive in recognizing the needs of nongame wildlife. In addition, we will need to develop techniques for defining habitat requirements like the one developed in the Pacific Northwest which relates wildlife-timber relationships to timber-management activities. The result was the ability to predict that "if I do this, I can expect to get that."

I have discussed briefly the history, need and justification for an expanded program of wildlife management that would include nongame and game species. The question is, how do we establish a program to fund nongame wildlife research and management when we can't completely fund the existing game management programs?

The "Federal Aid In Nongame Fish and Wildlife Conservation Act of 1977"(S. 1140) was introduced by Senator Gary Hart (Colorado) and eighteen co-sponsors on March 28, 1977. During hearings held on S. 1140 on August 3, 1977, a strong record of support was compiled for the concept of a nongame bill.

On July 28, 1977, Mr. Forsythe and Mr. Leggett introduced the "Nongame Fish and Wildlife Conservation Act of 1978" (H.R. 8606) in the House. The bill, which provides funds for both planning and implementation, also received favorable support. The Administration, as it did on S. 1140, withheld support.

The House has continued to work on a bill, and on December 7, 1977, Mr. Forsythe introduced H.R. 10255, a refined version

of H.R. 8606. It is a good bill and reflects more than 40 hours of work by the Committee legislative staff in cooperation with several conservation organizations. It provides for 90 percent matching money for planning and 75 percent for implementation. The planning portion lists 11 standards that, when adhered to, will help fill the voids in our knowledge of wildlife and its habitat requirements. Its major weakness is that it uses the authorized appropriation rather than an excise tax on certain outdoor recreational equipment and birdseed as the funding vehicle.

The momentum is there for the passage of this legislation and I feel I can truly say that nongame wildlife management is a need whose time has come. If I am right, or if I am wrong, we as professionals should consider Leopold's (1933) words of wisdom:

> Management of Other Wild Life. The objective of the game management program is to retain for the average citizen an opportunity to hunt. As already pointed out, this implies much more than the annual production of a shootable surplus of live birds to serve as targets. It implies a kind and quality of wild game living in such surroundings and available under such conditions to make hunting a stimulus to the esthetic development, physical welfare, and mental balance of the hunter.
>
> The objective of a conservation program for non-game wild life should be exactly parallel: to retain for the average citizen the opportunity to see, admire and enjoy, and the challenge to understand, the varied forms of birds and mammals indigenous to his state. It implies not only that these forms be kept in existence, *but that the greatest possible variety of them exist in each community.*

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The Relationship of Nongame Birds to Southern Forest Types and Successional Stages[1]

H. H. Shugart,[2] T. M. Smith,[3] J. T. Kitchings,[4] and R. L. Kroodsma[5]

Abstract.--This paper identifies general patterns of southern nongame bird species at three different spatial scales — the region, the forest stand, the microhabitat. Three hypothetical examples of nongame bird management are developed. Each example uses available information on nongame bird habitat requirements and tools used by forest managers. Possible future approaches to nongame bird management in the South are discussed.

INTRODUCTION

After several decades of research in avian ecology conducted by ornithologists in southern forests and elsewhere, we are in a position to generalize to a degree about the expected patterns of distribution of nongame birds over time and space. Two publications that may be useful for providing the reader with more detail are Slusher and Hinckley (1974) and Smith (1975). We will draw from these two volumes and current ecological literature to provide an outline of the general patterns of nongame birds and we will give some examples of approaches to managing nongame birds from our own research.

[1] Research sponsored in part by the Department of Energy under contract with Union Carbide Corporation and in part by the Eastern Deciduous Forest Biome, US-IBP, funded by the National Sciences Foundation under Interagency Agreement AG-199, DEB 76-00761.

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One important aspect in considering patterns of nongame birds is to pay close attention to the time and spatial scales that are being discussed. The general patterns of variation in nongame birds over regional spatial scales may be quite different from the patterns of some smaller scale such as a forest stand. We will discuss the dominant patterns in nongame birds at three spatial scales: in the southern region, on study sites of 10 to 20 hectares in size (the forest stand), and at a microhabitat scale (less than .5 ha). Within these spatial scales, we will discuss long-term, annual and seasonal patterns of variation. The patterns are summarized on Table 1 and more detailed references are given in the discussion that follows.

DOMINANT PATTERNS OF NONGAME BIRDS IN THE SOUTHERN FORESTS

We will discuss patterns of distributions of forest bird species in four of the nine categories in Table 1.

Long-Term Regional Patterns of Nongame Birds

Over longer time scales (considering decade to decade or longer patterns of variation in bird distributions), there have been several well documented cases of range extensions into the South. For example, such northern erratic migrants as the Evening Grosbeak and the Pine Siskin now occur regularly during some winters in parts of the South in which they had never been recorded before the present decade. There have been in the somewhat more distant past — a century ago — wholesale extinctions and regional extirpations of woodland species associated with the era of resource exploitation. Changes in species

Table 1. Dominant Patterns in Southern Nongame Forest Bird Communities Considered at Three Temporal and Three Spatial Scales. Topics in Italics are Discussed in More Detail in Text.

	LONG-TERM	ANNUAL	SEASONAL
REGIONAL	Long-term/regional patterns are studied by biogeographers. Patterns in the South are: 1. *The number of woodland species decreases as one moves south or away from mountains. (See MacArthur, 1972).* 2. *The number of endangered species increases as one moves south and into coastal areas. (See map in text).*	Work has been done in the past decade using the data from the U.S. Bureau of Sport Fisheries and Wildlife Breeding Bird Survey. Trends of increase and decrease of common and relatively less common bird populations can be documented with fair reliability. (See C. S. Robbins' paper below). It is now possible to measure effects of regional land management policies on the regional bird populations.	Considerable information has been collected on winter and summer distributions of nongame birds as well as on migratory birds. General patterns in the South are: 1. Typical overwintering species are nonwoodland birds. 2. Migrants often display habitat selection patterns that resemble the breeding season preferred habitats. 3. Breeding bird densities in forests are on the average of 2 to 4 breeding pairs per acre but during migration densities may be several times this figure.
FOREST STAND	Long-term/forest stand patterns are often termed "avian succession studies". General patterns are: 1. *Bird diversity generally increases with successional development of an area. This increase is strongly associated with the development of diverse vegetative structure.* 2. *There is great variation among studies but bird density often increases with age of a study plot.*	*There can be considerable variation from year to year at a given forest stand in terms of populations of a given species.* The annual species composition of dominant species is constant from year to year. There can be considerable variation in the presence or absence of "rare" species from year to year.	Patterns that have emerged from studies to date indicate: 1. Variation in population size within a breeding season can be considerable due to several biotic or abiotic factors (Wiens, 1975). 2. Between seasons both the density and diversity of woodland birds is highest during migration, next highest during the breeding season and lowest in the winter.
MICRO-HABITAT	It is generally thought that microhabitat preferences of birds change relatively slowly. There are some cases of species adapting to human habitat alterations but such adaptations do not promise to be of significance as an ameliorating factor when critical habitat is altered over a region.	Very little is known about year to year changes in microhabitat selection in species. Studies with mammals have indicated that such changes can occur in rodents. Most bird studies assume that year to year microhabitat preferences are reasonably constant. (See James, 1971 for niche gestalt concept).	*Studies using discriminant function analysis and other multivariate techniques show promise as a management tools. Such studies may allow the development of habitat management for nongame birds. Information on microhabitat can be used to incorporate bird habitat projections in forest stand simulators.*

ranges and the extinction (or potential thereof) of species can be summarized in two ways: (1) We can consider the patterns of overlap of species ranges to form a regional pattern of species richness (viz. areas in which many ranges overlap are species rich). We can then consider patterns of species richness over the South. (2) We can map the ranges of species that are considered to be in danger of extinction.

Species Richness

Several factors influence the richness (measured in terms of the number of species) of the South's regional breeding avifauna. Regions that have considerable topographic relief or great heterogeneity of habitat types tend to have more species than otherwise comparable areas. Florida is depauperate (has less species than one would expect) for a region with both temperate and tropical habitats. This relative lack of species is due to the fact that Florida is a peninsula and is isolated by the Gulf of Mexico from the sources of tropical species that might otherwise occur there (Cook 1969). It is the depauperate nature of Florida that has allowed it to be a "staging area" for the invasion of exotic species onto the North American continent.

In general, the greatest richness of non-game bird species is in the Appalachian region of the South. This richness is due in part to the altitudinal changes in the region and in part because the region is in a zone in which several species with northern affinities extend their ranges into the South. Table 2 provides a list of species occurring in these forests along with a general description of the species habitat preferences and nest site characteristics.

Endangered Species

If one maps the joint ranges of all of the so-called endangered bird species that occur in the South (Fig. 1) the resultant pattern is the inverse of that for species richness. The endangered species tend to be distributed in coastal areas (or on the coastal plain) and in the southern part of the region. Of these endangered species, most are not directly associated with forest habitats, but the Red-Cockaded Woodpecker (which is an old-age pine-forest endemic species) is often associated with areas that are managed for wood products. The management of land on which an endangered species occurs is a very difficult endeavor both from a legal standpoint and in terms of the practical management aspects. Many of the endangered species are

Figure 1.--Overlaps in ranges of endangered species in the South. The darkest shading on the map indicates areas in the range of five rare or endangered bird species, the lightest shading indicates areas in the range of only one rare or endangered bird species. Intermediate shadings indicate 2, 3, or 4 species increasing with intensity of map shading.

rare birds that are associated with an ecologically unique habitat type (e.g., Cape Sable Seaside Sparrow) and management for these species is often a matter of avoiding any alteration in the habitat in which the species occur. Species such as the Red-Cockaded Woodpecker and perhaps the Bachman's Warbler are rare but also occur in transient habitats (respectively, old-growth pine stands, and disturbed southern swamp-forests). One cannot manage land for such species simply by leaving areas alone that appear to be suitable habitat. Natural succession will transform the habitat in time to some other habitat type. The management for these species would have to include the creation of new habitat in adjacent areas. The management of southern forests to include as an objective the perpetuation of transient-habitat endemics such as the Red-Cockaded Woodpecker may be one of the most difficult tasks that the regional manager ever has to tackle.

Table 2. Habitat preferences of birds that breed in woodlands of the eastern United States[a], and their abundance in eastern mountain hardwood forests[b] during the breeding season

Species	Forest type(s) preferred[c]					Density--pairs per 100 acres (or frequency in all stands[b])[c]				Nest site preferred[d]
	1	2	3	4	5	6	7	8	9	
Occurring primarily in forest interior										
Cooper's Hawk			X				(2)[b]			B
Sharp-shinned Hawk			X				(1)			C
Broad-winged Hawk			X				(8)			B
Ruffed Grouse				X		1	+	+	+	G
Yellow-billed Cuckoo		X				+	1	1	1	U
Black-billed Cuckoo		X				+	2	+	+	U
Barred Owl		X					(7)			D
Saw-whet Owl			X				(0)			O
Chuck-will's-widow			X				(0)			G
Whip-poor-will			X				(8)			G
Pileated Woodpecker				X		+	+	+	1	O
Red-bellied Woodpecker				X		1	+	+	1	O
Yellow-bellied Sapsucker				X		+	0	0	1	OD
Hairy Woodpecker				X		+	+	+	1	OD
Downy Woodpecker			X			3	1	+	2	O
Great Crested Flycatcher				X		2	1	2	2	OD
Acadian Flycatcher		X				4	2	3	28	
Least Flycatcher				X		4	0	0	1	B
Eastern Wood Pewee				X		5	5	5	5	D
Black-capped Chickadee			X			1	4	1	2	OD
Carolina Chickadee			X			3	1	+	4	O
Tufted Titmouse		X				3	2	4	9	OD
White-breasted Nuthatch		X				5	2	6	15	OD
Red-breasted Nuthatch	X						(1)			
Brown Creeper			X				(1)			between bark and trunk
Winter Wren			X			0	0	0	+	exposed roots
Wood Thrush		X				5	2	6	15	U
Hermit Thrush					X		(2)			G
Veery		X				8	5	4	3	G
Blue-gray Gnatcatcher		X				3	2	6	9	
Golden-crowned Kinglet	X						(0)			C
Solitary Vireo					X	+	+	2	2	CU
Red-eyed Vireo		X				18	23	21	37	U
Black-and-white Warbler		X				9	6	9	5	G
Swainson's Warbler		X				0	0	0	+	U
Worm-eating Warbler		X				2	+	+	9	G
Nashville Warbler			X				(0)			G
Parula Warbler			X			+	0	+	1	B
Magnolia Warbler	X					1	+	+	2	CU
Black-throated Green Warbler					X	3	5	5	7	CU
Black-throated Blue Warbler					X	8	4	6	4	U, CU
Cerulean Warbler		X				2	0	3	17	D
Yellow-throated Warbler			X			0	+	0	0	B
Blackburnian Warbler			X			1	+	1	3	C
Pine Warbler	X					+	3	+	+	C
Ovenbird		X				14	11	17	17	G
Kentucky Warbler		X				3	0	7	5	G
Hooded Warbler		X				14	5	4	6	U
Canada Warbler				X		1	+	8	3	G
Scarlet Tanager				X		7	+	3	7	D
Rose-breasted Grosbeak		X				1	3	1	2	U
Occurring primarily in forest edge, brush, and areas with scattered trees										
Sparrow Hawk (American Kestrel)			X				(0)			O
Bobwhite			X				(1)			G
Mourning Dove			X				(2)			B
Common Flicker			X			2	+	1	1	O
Eastern Kingbird		X					(0)			D
Willow Flycatcher			X				(0)			U
Olive-sided Flycatcher					X		(0)			C
House Wren		X				0	0	0	+	O
Mockingbird			X				(0)			U
Brown Thrasher			X			0	0	+	0	U
Robin			X			+	1	1	1	B
Eastern Bluebird			X				(0)			O
Cedar Waxwing			X				(9)			B
White-eyed Vireo			X			+	0	0	0	U
Yellow-throated Vireo		X				2	1	1	3	D
Warbling Vireo		X					(0)			D
Prothonotary Warbler		X					(0)			O
Golden-winged Warbler			X			6	+	0	0	G
Blue-winged Warbler			X			0	0	0	+	U
Yellow Warbler		X				0	1	0	+	U
Chestnut-sided Warbler		X				19	2	1	4	U
Prairie Warbler			X			3	1	+	+	U
Louisiana Waterthrush		X				2	+	+	1	stream banks
Yellow-breasted Chat			X			4	+	+	+	U
Mourning Warbler			X			4	+	0	1	G
American Redstart				X		3	+	+	16	U
Orchard Oriole		X					(0)			D
Blue Grosbeak			X				(0)			U
Indigo Bunting			X			13	8	1	2	U
Rufous-sided Towhee			X			19	2	9	7	G
Slate-colored Junco			X			4	+	6	3	
Chipping Sparrow			X				(1)			U
Song Sparrow			X			1	+	0	0	G
Occurring in forest interior and edge, brush and areas with scattered trees										
Turkey Vulture			X				(2)			G
Black Vulture			X				(0)			G
Red-tailed Hawk			X				(2)			B
Red-shouldered Hawk			X				(3)			B
Screech Owl			X				(2)			O
Great-horned Owl			X				(1)			B
Ruby-throated Hummingbird			X			1	1	+	+	U
Red-headed Woodpecker		X					(0)			OD
Blue Jay			X			+	+	+	1	B
Common Crow			X				(26)			B
Carolina Wren			X			0	+	0	4	U,O
Catbird			X			1	+	1	1	U

Species	Forest type(s) preferred[c]					Density--pairs per 100 acres (or frequency in all stands[b])[c]				Nest site preferred[d]
	1	2	3	4	5	6	7	8	9	
Northern (Baltimore) Oriole		X						(4)		D
Summer Tanager				X		1	+	+	2	B
Cardinal			X			4	1	2	8	U
White-throated Sparrow			X					(0)		

[a]All species that breed east of a line from western Louisiana to western Minnesota are included except species that are rare or have very small breeding ranges within this area.

[b]The four density estimates for each species represent the average number of breeding bird pairs per 100 acres in the following four types, respectively, of mountain hardwood forests from North Carolina to New York: cutovers (N = 7 stands); stands of young forest with average canopy height = 25-30 feet (N = 5); stands of medium-aged forest with average canopy height = 35-45 feet (N = 7); and stands of mature forest with average canopy height > 50 feet (N = 11). Plus signs (+) indicate densities between zero and one pair per 100 acres. Each single number in parenthesis represents the number of stands (out of a total of 30 stands) in which the particular species was noted as a visitor or occurred too infrequently to allow density estimation. Data were obtained from census reports in American Birds, many of which were contributed by the Brooks Bird Club.

[c]1 - coniferous, 2 - deciduous, 3 - deciduous and coniferous, 4 - deciduous and deciduous-coniferous, 5 - coniferous and deciduous-coniferous, 6 - cutovers, 7 - young, 8 - medium-aged, and 9 - mature.

[d]Abbreviations for nest sites are as follows: D = deciduous trees, C = coniferous trees, B = both deciduous and coniferous trees, O = cavities, OD = cavities in deciduous trees, U = broadleaf undergrowth (sometimes low tree branches), CU = coniferous undergrowth, and G = ground.

Long-Term Patterns of Nongame Birds at the Scale of the Forest Stand

Patterns in Breeding Bird Diversity

Diversity indices as used by most ecologists (see MacArthur and MacArthur 1961; Patten 1962; Lloyd and Ghelardi 1964; Monk 1967; for various uses of diversity indices with different sorts of organisms) can be thought of as having two components:

Richness — the number of species in a given community.

Equitability — the evenness of numerical abundance of the populations in a given community.

For breeding bird communities the diversity is mostly due to the number of species (richness) (Tramer 1969; Kricher 1972) so that for studies of similar sampling intensity and size, diversity (often calculated as $H' = \Sigma p_i \mathrm{Log} p_i$, where H' is the diversity index and p_i is the frequency of occurrence of the ith bird species) varies directly with species richness. The diversity index is not as strongly influenced by rare species as is a species list, and is useful in comparing studies of differing sample intensity (Buzas and Gibson 1969).

There is a general theory that species diversity of organisms should increase through succession with a decline in diversity in the last successional stages (Margalef 1958). This pattern has not been uniformly noted in studies of breeding birds and is almost certainly not the case in winter bird populations. Adams (1908) listed species of birds characteristic of successional stages (aquatic communities to bogs to climax forests) on Isle Royale, Michigan. Adams found a greater variety of bird life (species richness) in the intermediate stages of succession. Figure 2 (from Smith 1975) shows the pattern for three more recent studies. In no case is a decline in species diversity toward the end of succession particularly evident, but there is a tendency for diversity to increase through succession. There is considerable variation in pattern among the three studies.

Patterns of Breeding Bird Density

An increase of avian density through a progression of successional communities has been documented by Saunders (1936) in New York, Kendeigh (1948) in Michigan, Odum (1950) in North Carolina, Johnston and Odum (1966) in Georgia, Haapanen (1965) in Finland, Karr (1968) in Illinois, Karr (1971) in Panama, Shugart and James (1973) in Arkansas.

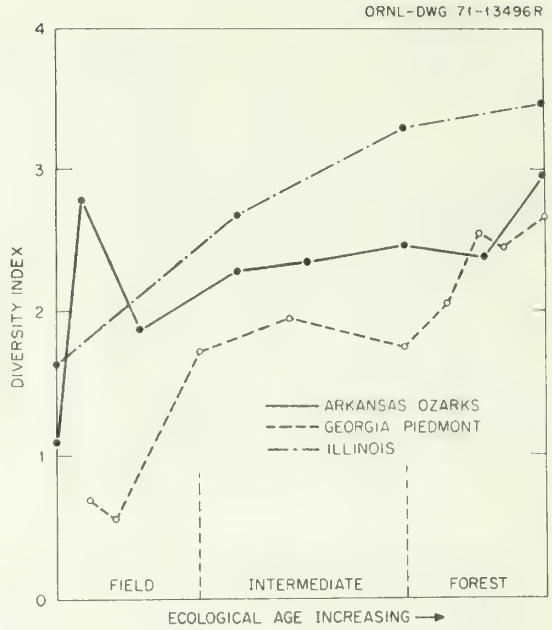

Figure 2.--Changes in the species diversity index (H') for bird communities during ecological succession. The Arkansas data are from Shugart and James (1973); Georgia data from Johnson and Odum (1950); Illinois data from Karr (1971). Figure modified from Shugart and James (1973).

These findings drawn from diverse regions are in general agreement. There are notable exceptions to this general pattern [e.g., Kendeigh (1947) found highest bird densities in shrubby seral stages of communities in the Helderberg Plateau region of New York]. However, there is an expected pattern of higher densities of birds in mature forests.

Annual Changes in Bird Communities at the Scale of the Forest Stand

A second time scale important at the level of the forest stand is that of annual or year-to-year variation in the composition of avian communities. This annual variation can take two forms: variation in the population of a given species, and annual variation of the species composition of the community as a whole. Figure 3 shows the annual fluctuations in the number of breeding pairs of selected bird species in an Illinois woodland over a period of years.

The actual causes for such yearly fluctuations in species abundance are for the most part unknown. Wiens et al. (1974) found no clear relationship between fluctuations in population size of avian species and climatic variation. The problem of identifying causal

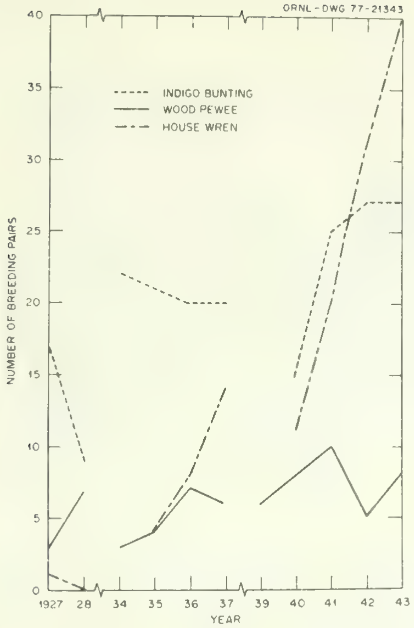

Figure 3.--Number of pairs of selected species of breeding birds in Trelease Woods, Urbana, Illinois (55 acres). Data from Kendeigh (1944).

factors is confounded by the fact that many of the breeding species in an area are migratory species whose densities may be a result of factors taking place in other areas of their range. Fluctuations may also be a result of changes in dispersal (distributional) patterns rather than absolute numbers. Territory size in avian species has been found to be negatively correlated with abundance of food within the territory (Stenger 1958; Schoener 1968). As a result of this, annual variations in the number of breeding birds of a particular species in a given stand might be a result of varying territory size resulting from variations in the food supply (i.e., insect biomass).

Annual turnover of species in a stable vegetation type is rather insignificant in mainland regions and usually reflects the presence of "rare species" encountered during censuses. The actual species composition of the dominant segment of the avifauna changes little from year to year for a given site.

Seasonal Patterns in Bird Microhabitat Selection

One of the more interesting lines of research to develop over the past decade has been the use of multivariate statistical techniques to quantify the microhabitat selection patterns of select nongame bird species usually within a season. Schoener (1974) has reviewed the manner in which similar species utilize their environments and has noted the following general patterns:

1. The important variables involved in resource partitioning are typically habitat variables, followed in importance by food variables.

2. As the number of species considered in a community increases, the number of variables needed to separate the ecological roles of the species increase.

Recently, there have been multivariate statistical analyses (James 1971; Shugart and Patten 1972; Anderson and Shugart 1974; Whitmore 1975) directly applied to determine the influence of a number of habitat variables on the distributions and microhabitats of entire avian communities. These studies indicate that the simple relationship between bird species diversity and foliage height diversity first presented by MacArthur and MacArthur (1961) is neither as direct nor as universally applicable as it was first thought. The application of multivariate analysis to the habitat selection problem in birds also seems to reduce problems in data interpretation.

For example, one application of discriminant function analysis has been proposed by Conner and Adkisson (1976) to determine potential woodpecker inhabitation by measuring variables in the structural vegetation. Discriminant function analysis can also be applied to the entire woodpecker community in order to identify differences in structural niche requirements among species. Using data collected by R. Bunnell on a study area on the Department of Energy Oak Ridge Reservation, a discriminant function was computed so that given the vegetational structure at a given point in space, the probability of the point being utilized by a given woodpecker species could be determined. Vegetative data that corresponded to the parameters used in the woodpecker habitat analysis had been collected for a number of inventory plots on the Oak Ridge Reservation (Bunnell et al. 1978) where no survey of woodpecker species have been made. These data were fed into the discriminant function and the most probable woodpecker species associated with each inventory plot was computed. The resultant map (Fig. 4) made with Symap (Dougnik and Sheeham 1975) shows the potential woodpecker feeding habitats by species for a site called the Haw Ridge Site. Such a map could be used by a resource manager to avoid the areas that might be used by a given woodpecker species or it might allow the placement of a nature trail so that a visitor could expect to see all the indigenous woodpecker species with minimum effort. The idea of coupling microhabitat analysis with the

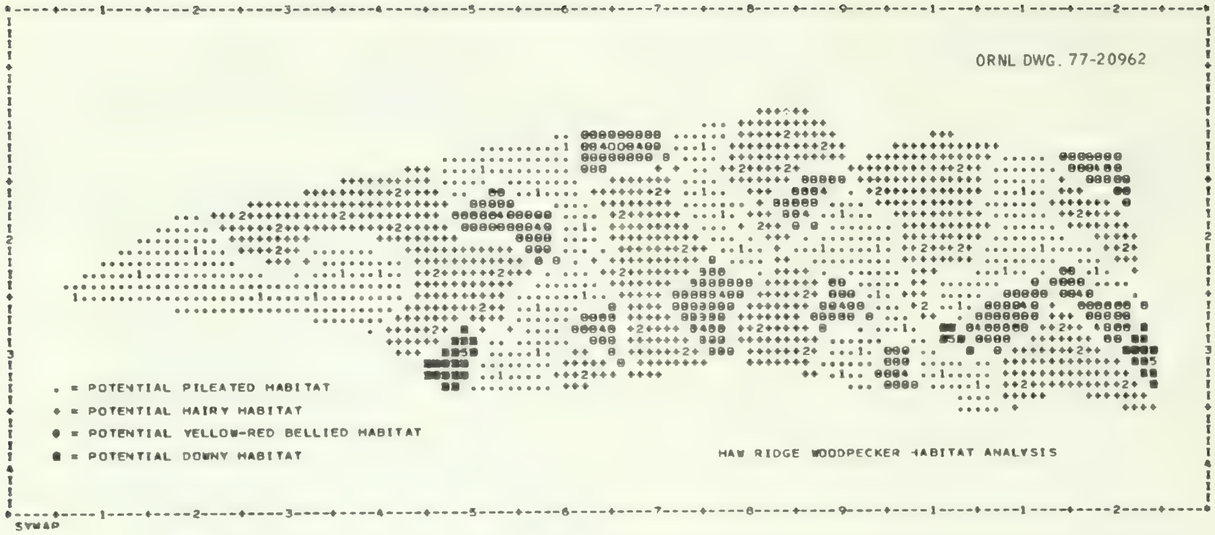

Figure 4.--A Symap map of potential woodpecker habitat on a study site called Haw Ridge on the Department of Energy Oak Ridge Reservation. The map was drawn using a discriminant function (calculated on a base data set) to determine the expected woodpecker species at each of the forest inventory plots on Haw Ridge. Yellow-bellied Sapsucker and Red-bellied Woodpecker habitats are similar and are lumped together.

forest inventory sample plots used by resource managers creates the potential for nongame management comparable to those used for many game species.

POSSIBLE NEW METHODOLOGIES FOR NONGAME BIRD MANAGEMENT

Regional Modeling of Nongame Bird Management

Shugart et al. (1973) formulated a rationale and methodology for constructing models of forest succession over large land areas (10^8 - 10^{10} acres). In developing this methodology an example model was used to simulate changes in amounts of forested land of various successional stages in the State of Michigan. Models of this type allow for long-term predictions to be made concerning the areas of land covered by a particular forest type. For species in which the preferred habitat can be easily associated with a forest type (as opposed to species that have specific microhabitat preferences — discussed below), such simulators can be used to project the long-term regional consequences of different management strategies.

As a purely hypothetical example of how one might couple a regional-inventory projection model to the habitat selection patterns of a given species, we will consider how the habitat available to the Kirtland's Warbler might change in the face of two different management schemes. We will use the Shugart et al. (1973) example model as a succession simulator and will consider only the gross habitat selection patterns of the Kirtland's Warbler. Kirtland's Warbler is an endemic of the Jack Pine forests of northern Michigan. It is restricted to the fairly dense stands of young Jack Pines that spring up after forest fires (Bent 1963). As a result of current fire prevention practices, the Jack Pine forests, being an early successional forest type, are quickly declining in area. Subsequently the population of Kirtland's Warbler has declined drastically to the point at which today it is an endangered species.

Results of a 250-year simulation of the Jack Pine forests of Michigan under conditions both of natural succession (in the absence of natural or man-made disturbance) and of harvesting with a rotation age of 50 years, is shown in Fig. 5. Under conditions of natural succession Jack Pine decreases to 1/10 of its original area (of 671.5 X 10^4 acres) within 100 years and continues to decrease to 1.09 X 10^4 acres by the end of the 250-year simulation. When timber harvest and replanting is introduced to the model, equilibrium occurs for Jack Pine at the onset of the simulation with total area covered varying by less than 2% over the 250 years.

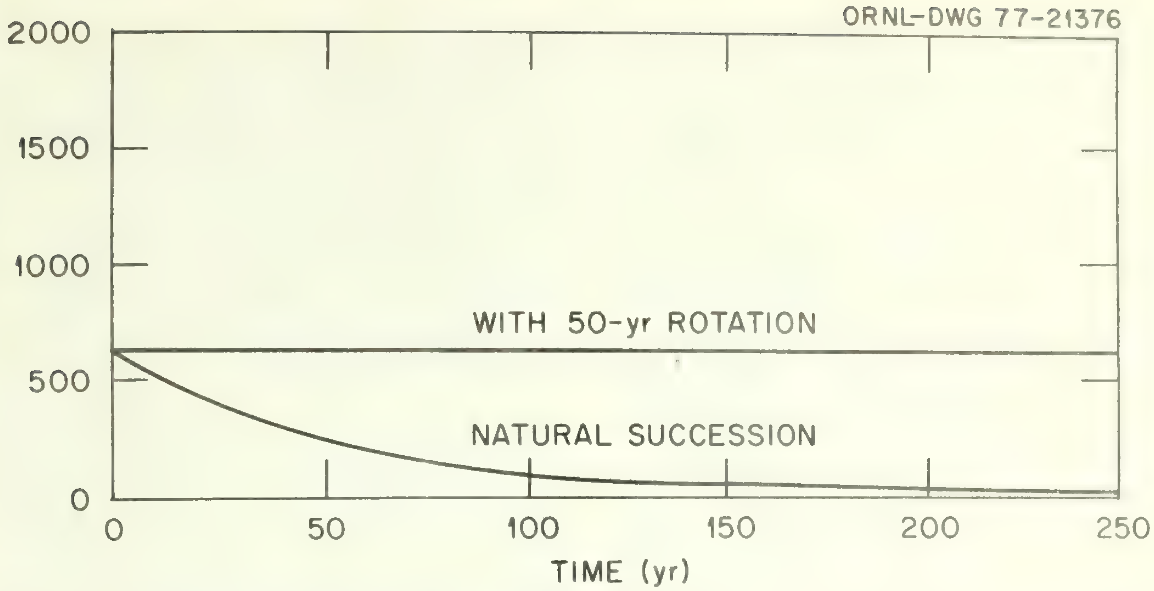

Figure 5.--Total acreage of Jack Pine in Michigan through 250 years of simulated succession with and without forest management. (Vertical axis in acres X 10^3)

In actual fact, to deal with this problem of declining habitat availability for Kirtland's Warblers under present conditions, selected areas of Jack Pine forest are being set aside and periodically burnt to make available young stands of suitable habitat. The value of models such as the one above, is in their ability to predict long-term trends in the availability of habitat types under various management practices. In the above simulation, the harvesting of Jack Pine using the equivalent of a fifty-year rotation period appears to maintain the present status of Jack Pine as a forest type and thus halt the decline of available Kirtland's Warbler habitat.

In this hypothetical example we have coupled a computer model (that projects the regional inventory of different forest types into the future) to the gross habitat preferences of a nongame bird species. Models which project future forest cover are being used and developed for forest systems for many regions of the United States. Some of these models even take into account economic feedbacks that might alter the harvest and site preparation options (for example) that are used (see Shugart et al. 1977 for a review of some of the more ecologically oriented models of this sort). Given the existence of regional "habitat projection models" — which is what the models used to project state forest inventories really are — we are in a position to incorporate bird habitat preferences into these models and to manage nongame bird habitats.

Stand Modeling of Nongame Bird Management

Just as we can use regional inventory projection models to predict the changes of suitable habitat for species over an entire state, we can also use stand simulators to assess effects of alternate management strategies on selected bird species or for entire bird communities. Stand simulation models are reviewed in Horn 1977; Shugart et al. 1977. These models are quite varied in the types of mathematics used but they typically function by considering the tree by tree changes over time for an area that corresponds to that of a canopy tree or to some sampling unit. The spatial scale of these models corresponds to the scale of what we earlier termed the microhabitat spatial scale for birds.

As a hypothetical example, we took the stand simulator (FORET) that has been developed for East Tennessee (Shugart and West 1977) and used the model to simulate 1000 years of natural succession on 100 plots of forested land each of which is 1/12 ha (∿ 1/5 acre). This particular model functions by keeping track of the diameter and species of each individual tree occurring on the simulated plot. Each year, a probability of mortality for each individual tree is determined and a random number is drawn to determine if a given tree should be killed. Similarly, according to conditions on the forest plot, trees of different species become established either by seeding in or by sprouting. Each year the diameter of each tree is increased according to the species and size of the tree and taking into account shading, crowding and climate. The output from the model is in the form of lists of tree diameters by species per 1/12 ha. This output looks like a stand tally sheet and is provided each year

for each simulated plot. By combining the output from several replicate runs (usually 100) we can see the dynamics of a forest. Output from the model, and a discussion of the validation of this model are in Shugart and West 1977.

The model output from 100 plots for 1000 years of natural succession was converted to biomass (in metric tons ha^{-1}). We then apportioned this biomass between thin-barked tree species and thick-barked species. The thin-barked trees were the species that the Yellow-bellied Sapsucker might use for feeding. The Yellow-bellied Sapsucker (occurring in winter throughout the South) feeds on the inner bark, tree sap and the insects drawn to the holes that the bird maintains in selected trees. Figure 6 shows the percentage of trees that

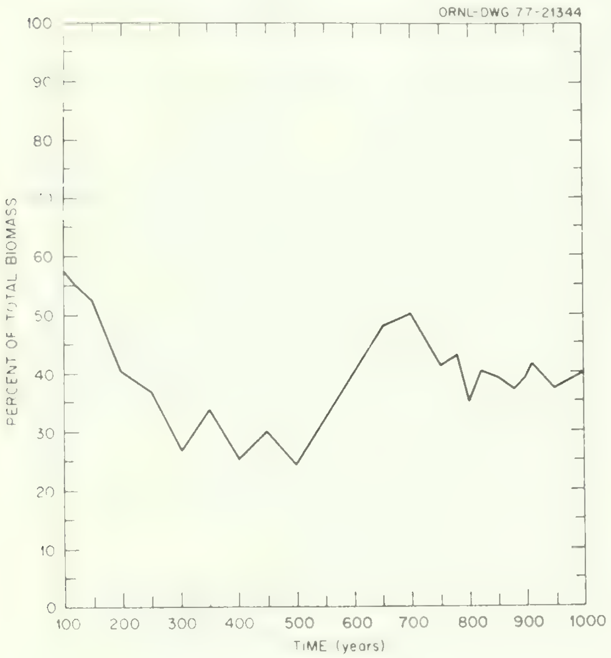

Figure 6.--Thin-barked tree species suitable for feeding by Yellow-bellied Sapsuckers as a percentage of the total biomass through 1000 years of simulated stand development on 100 1/12 ha circular plots.

might be fed upon by Yellow-bellied Sapsuckers during 1000 years of natural succession in East Tennessee. There are two periods early and late in the succession in which sapsucker trees are particularly available but in no case is there a shortage of potential feeding sites during natural succession in the East Tennessee forests.

There are several logical extensions of this sort of habitat modeling. We could have increased the mortality probability for trees utilized by sapsuckers to obtain an estimate of the effect of this bird on the patterns of forest succession. We could harvest trees from the simulated stands and assess the effect of any stand management scheme on the availability of sapsucker feeding sites. Using multivariate statistical descriptions of habitat structure associated with different bird species, we could simulate bird community changes under natural succession or under various management options. What is needed in this case is a stand projection model and a knowledge of species habitat preferences.

FUTURE PROBLEMS IN NONGAME BIRD MANAGEMENT

Through this discussion we have focused on the habitat preferences of southern nongame birds at different spatial and temporal scales. We have provided some general rules-of-thumb for patterns of bird populations and we have given three examples of what we feel will be the nature of future nongame bird management. It is imperative for the development of nongame bird management as a scientifically sound system of management practices that we learn more about the habitat requirements and niche relationships of nongame birds. Many temperate bird species (at least within a given season) seem to be closely tied to certain microhabitat features. This probably is not the case with all temperate species and seems not to be the case in general in tropical birds (Able and Noon 1976). We must know which species are associated with which habitat elements and we must know which species cannot be managed by simply managing for habitat.

It is probable that management for nongame species will be practiced in the less-economically important mountain forests of the Arkansas and Missouri Ozarks and in the Southern Appalachians due to several ecological and economic factors. These forests are already used in a primary fashion for outdoor recreation so that the political pressures and incentives may be greatest in these regions for a concerted effort to manage song birds. Also these forest systems have a rich avifauna. The economically important pine-dominated forests of the coastal plain should not be overlooked in terms of their potential for nongame bird management. The richer bird communities may be in forests of the southern mountains, but not all species occur in abundance in these regions and some species are more or less endemic to the coastal plain and piedmont ecosystems. There is a potential for ignoring nongame bird populations in the pine forests that could create shortages in critical habitat for some species in the future. This potential problem should be recognized and avoided.

We have identified two areas in which tools and data familiar to the forest manager could be used to attempt to optimize birds and other uses of forests. The first area involved the use of forest inventory data as habitat potential data for nongame species. The second area involved using stand and regional forests simulators to project bird habitat availability into the future. There is undoubtedly more to nongame bird management than simply habitat management but much work needs to be done in this area. The insights of the forest-entomologist would be invaluable in studying food availability for nongame birds, for example. The richest research area in nongame bird management in the future may well be the combining of the present understanding of avian ecology with the experience in managing forests.

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The Structure and Organization of Avian Communities in Forests

Sidney A. Gauthreaux, Jr.[1/]

Abstract.--The structure of bird communities is presented in the context of Southwood's schema of ecological strategies and the habitat templet. Heterogeneity in space and time and their effects on the gradients of durational stability and of resource level and constancy are considered the underlying factors in community organization. These gradients are used in discussing species strategies and life forms, community process (succession), and community characters (spatial complexity, trophic complexity, niche breadth, standing crop, turnover, and diversity).

INTRODUCTION

The concept of community as an aggregate of organisms which form a distinct ecological unit defined in terms of flora and fauna is widely accepted, but it is also obvious that the concept includes complex dynamic interactions and properties of the component species. In this presentation I will give a broad overview of the structure of avian communities in forests. In discussing avian community ecology I should mention that it is a bit naive to speak of "avian" community ecology, because birds represent but a part (and some would say a rather insignificant part) of the total community structure. Nonetheless, work on birds has contributed greatly to our knowledge of the structure and dynamics of ecological communities, and it is this contribution I wish to stress in this paper.

The ultimate objective in studying community ecology is to determine the nature and the relative importance of the factors controlling its composition; also, whether, to what extent, and why the community is changing with time (Pielou 1974). In order to achieve this objective it is necessary to define some measurable properties of the community as a whole and in so doing make possible comparsons of the quantitative properties among several communities. As Pielou (1974) points out, this is a necessary first step toward an understanding of how communities function. Thus, the study of bird communities is the search for relations among measurable aspects of sets of bird species such as patterns of size or relative abundance among the species within a community and patterns of numbers of species that vary regularly from community to community (MacArthur 1971).

Southwood (1977) has recently stressed the importance of time and space in terms of ecological strategies of species in communities and emphasized that the strategies of the species have evolved to maximize the numbers of their descendents in the community. He has generated a schema in which various features of communities have been arranged against the axes of space and time (fig. 1). Southwood's schema will be used as a guideline in my treatment of avian community ecology. It should be noted that any consideration of avian communities involves treatment of component species' strategies, community process (succession), and community characters (spatial complexity, trophic complexity, niche breadth, standing crop, turnover, and diversity), and these considerations will serve as the outline for my presentation.

COMPONENT SPECIES STRATEGIES

A number of recent studies have addressed life history strategies from many different viewpoints. In a theoretical examination of optimal reproductive efforts, Schaffer (1974a) has relaxed the general assumption of environmental constancy, and Schaffer (1974b) and Schaffer and Rosenzweig (1977) have investigated

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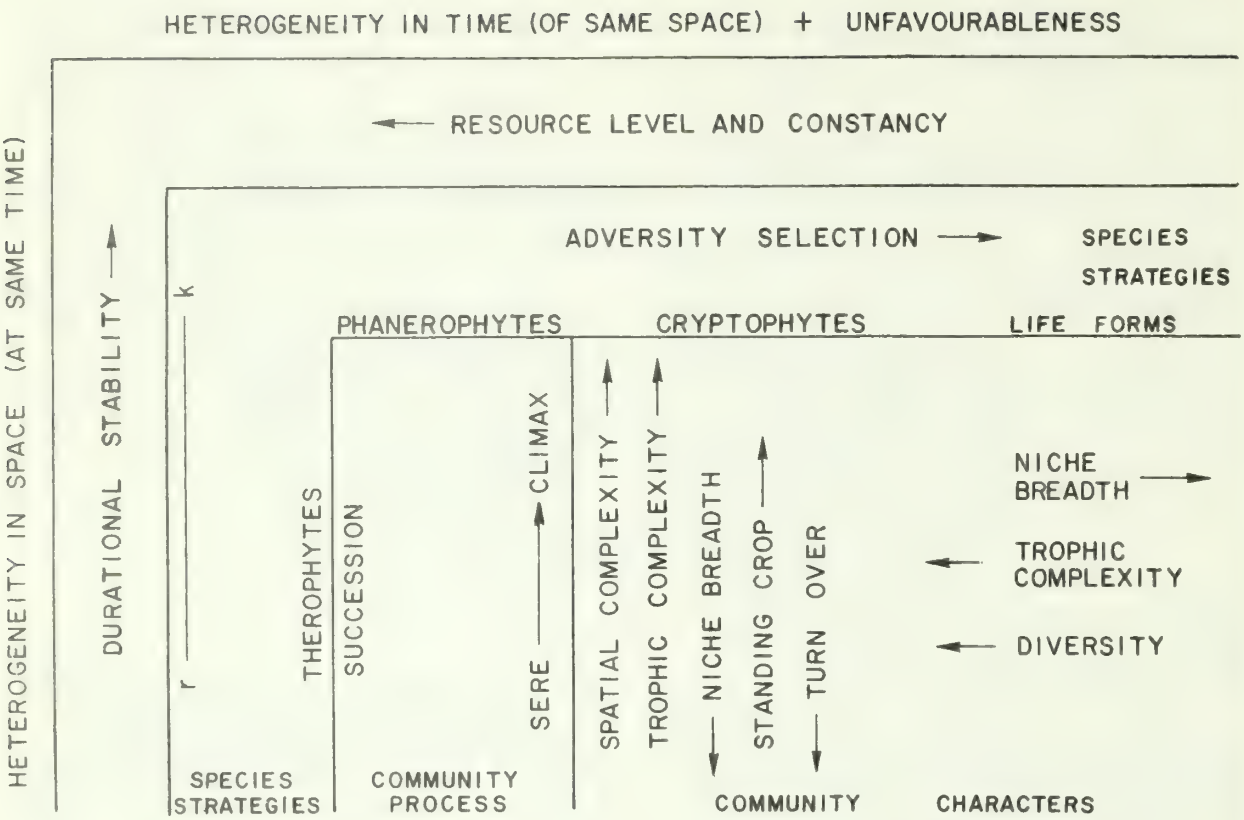


Figure 1.--Ecological strategies and the habitat templet (after Southwood 1977).

the problem of more than one life history strategy in a species. The influence of environmental certainty, trophic level, and resource availability in life history strategies have been discussed by Wilbur et al. (1974), and they suggest that additional ecological dimensions, such as environmental predictability and the relative trophic position of species may be important in the evolution of life histories. Nichols et al. (1976) agree that attempts to explain life histories as outcomes of single selective pressures have actually obscured the evolution of life history strategies, and they add that numerous organisms inhabiting variable environments exhibit temporally dynamic reproductive strategies (see also Giesel 1976). Ricklefs (1977) in a discussion of the evolution of reproductive strategies in birds suggests that the diversity in life histories must be sought primarily in environmental factors that directly influence fecundity, prereproductive survivorship, and adult mortality and in density-dependent or fortuitous relationships among those aspects of the environment.

Pianka (1970, 1974a:90) has tabulated several characteristics correlated with r- and K-selection (Table 1). Stearns (1976, 1977) has carefully examined the ideas and correlates of r- and K-strategists in an overview of life history tactics, and questions the validity of the underlying assumptions and theoretical predictions that have flourished in the literature. According to Stearns (1976), the key life history traits are brood size, size of young, the age distribution of reproductive effort, the interaction of reproductive effort with adult mortality, and the variation in these traits among an individual's progeny. The general theoretical problem is to predict which combinations of traits will evolve in organisms living in specific circumstances. Leon (1976) has addressed this problem in part by using optimal control theory.

Some bird species resemble r-strategists (see MacArthur and Wilson 1967) in that they have high reproductive potential (longer breeding seasons and raise more broods per year than do other species), extraordinarily catholic and unspecialized habitat preferences, high dispersal ability, and are competitively excluded from species-rich islands by K-selected species (Diamond 1975). These former species are called supertramps, and Diamond found that faunas dominated by supertramps maintain population densities up to nine times higher than those of K-selected faunas of the same number of species.

Table 1.--Some of the Correlates of *r* and *K* Selection (After Pianka 1970, 1974:90).

	r Selection	*K* Selection
Climate	Variable and/or unpredictable; uncertain	Fairly constant and/or predictable; more certain
Mortality	Often catastrophic, nondirected, density independent	More directed, density dependent
Survivorship	Often Type III	Usually Types I and II
Population size	Variable in time, nonequilibrium; usually well below carrying capacity of environment; unsaturated communities or portions thereof; ecologic vacuums; recolonization each year	Fairly constant in time, equilibrium; at or near carrying capacity of the environment; saturated communities; no recolonization necessary
Intra- and interspecific competition	Variable, often lax	Usually keen
Selection favors	1 Rapid development 2 High maximal rate of increase, r_{max} 3 Early reproduction 4 Small body size 5 Single reproduction	1 Slower development 2 Greater competitive ability 3 Delayed reproduction 4 Larger body size 5 Repeated reproductions
Length of life	Short, usually less than 1 year	Longer, usually more than 1 year
Leads to	Productivity	Efficiency

It should be emphasized that although some bird species may be thought of as r-strategists, birds as a whole, compared with many other groups of organisms (e.g., insects), are more K-strategists on the r-K continuum. Southwood et al. (1974) have made brief reference to birds as r- and K-strategists and have concluded that while many vertebrate species may have arisen as a result of K-selection (in comparatively stable geological periods), many groups within these taxa have had their population parameters modified to conform to the habitats they occupy. Really successful K-strategists become precisely adapted to a very permanent (in generation terms) habitat type, they become larger in size, and, because of their extreme K-type population parameters, they lose their plasticity for selection. Another clear and straightforward discussion of optimal life history strategies with some reference to birds can be found in Southwood (1976). Brewer and Swander (1977) have examined life history traits as they influence the intrinsic rate of natural increase in forest, grassland, and marsh inhabiting birds. They conclude that forests can probably be thought of as K-selecting environments for birds, while grasslands and marshes probably are not, specifically "because vegetational fluctuations make particular areas unpredictably uncrowded or overcrowded."

SUCCESSION

The appearance of species population densities along the time axis during succession is fundamentally similar to that found along spatial gradients (see fig. 1), but the rate of change slows as the community matures (Whittaker 1975). The properties of succession have been thoroughly reviewed by Margalef (1968), Odum (1969), Horn (1974, 1975, 1976), and Whittaker (1975). Succession is being viewed currently in the context of adaptations of individual species independent of any transcendent properties of the whole community (Drury and Nisbet 1971, 1973; Connell 1972; Horn 1974), and the replacement process is increasingly being represented by Markovian models (Horn 1976). The mechanisms of succession in natural communities and their role in community stability and organization have been reviewed recently by Connell and Slatyer (1977). They have suggested that the sequence of species observed after a relatively large space is opened up is a consequence of the following mechanisms. Species with broad dispersal powers

and rapid growth to maturity usually arrive first and occupy empty space. These species cannot invade and grow in the presence of adults of their own or other species. Several alternative mechanisms may then determine which species replace these early occupants. Connell and Slatyer (1977) have proposed three models of such mechanisms. The first they call the "facilitation" model that suggests that the entry and growth of the later species is dependent upon the earlier species "preparing the ground," and only after this can later species colonize. The second they have referred to as a "tolerance" model which suggests that a predictable sequence is produced by the existence of species that have evolved different strategies for exploiting resources. Later species will be those able to tolerate lower levels of resources than earlier ones. The third model they have called the "inhibition" model which suggests that all species resist invasions of competitors. The first occupants preempt the space and will continue to exclude or inhibit later colonists until the former die or are damaged, thus releasing resources that permit later colonists to reach maturity. The first and third models have the greatest supportive evidence, while the second model has little supportive data.

Kendeigh (1945) has long considered the general pattern of avian succession to be a manifestation of the habitat preferences and ecological requirements of the bird species. The replacement sequencing and habitat requirements of bird species during succession in a number of different communities have been examined (Adams 1908; Lack 1933; Grange 1948; Odum 1950; Beckwith 1954; Johnston and Odum 1956; Martin 1960; Mitchell 1961; Haapanen 1965, 1966; Karr 1971; Glowacinski 1972; Shugart and James 1973; Kricher 1973; Meslow and Wight 1975; Soots and Parnell 1975; Winternitz 1976), and all show that there is a high correlation between bird species and vegetation stage (fig. 2). Bond (1957) and Shugart and James (1973) have analyzed the correlation between bird and plant similarity coefficients between successional stages in communities and found that the correlations were both strong and significant.

The progressive changes in the composition and relative abundance of various bird species with the cropping of the forest on a 40-year cycle in Burgundy, France, has been examined by Ferry (1960). He found that the birds could be placed in four groups according to their responses to the changing environment. The first group of birds settle in the low herbaceous or bushy layer with open spaces above it, increase in density, and then disappear quickly. The second group consists of species that arrive fairly quickly after the felling, increase in density, and then slowly decrease without disappearing completely (provided the forest is not permitted to return to climax). The third group includes those birds that settle at a particular, more or less early, stage, increase rapidly at first, and then more slowly as the populations build up to their limit. The fourth group contains those birds whose populations passed through a maximum during the early stage, diminish or disappear when the undergrowth becomes too dense, and become abundant once again in the mature plots. Similar findings have been reported from studies undertaken in different environments, notably in pine forests in Britain (Lack 1933), spruce forests in Finland (Haapanen 1965, 1966), and in several different communities in America (Monson 1941, Hagar 1960, Kilgore 1971, Curtis and Ripley 1975, Webb et al. 1977).

COMMUNITY CHARACTERS

According to Southwood's (1977) schema (fig. 1), certain community characters (spatial complexity, trophic complexity, niche breadth, standing crop, and turnover) change during succession while some community characters (niche breadth, trophic complexity, and diversity) also vary in terms of resource level and constancy and in terms of saturation or interaction selection, exploitation selection, and adversity selection (see Whittaker 1975). It should be stressed that the aforementioned community characteristics are highly correlated and interactive and, consequently, it is almost impossible to discuss a given community character without making reference to another characteristic with which it is highly correlated (e.g., species diversity and trophic complexity). In the following sections I will examine the community characteristics given by Southwood (1977) with particular emphasis on birds.

Spatial Complexity

Through successional stages, the spatial complexity of a location increases and the variety of niches also increases. MacArthur and Levins (1967) have suggested that increasing the dimensionality of resources allows more species to inhabit a community, and MacArthur (1971) has emphasized that any habitat containing many kinds of patches will contain bird species appropriate to these patches.

A number of studies have attempted to examine the relation between increasing spatial complexity of vegetation in a community and avian community organization (Cody 1974; Tomoff 1974; Wiens 1974, 1976; Willson 1974; Balda 1975; Roth 1976; Pearson 1977). There is agreement that more than one measure of complexity is needed. For example, vertical measures such as foliage

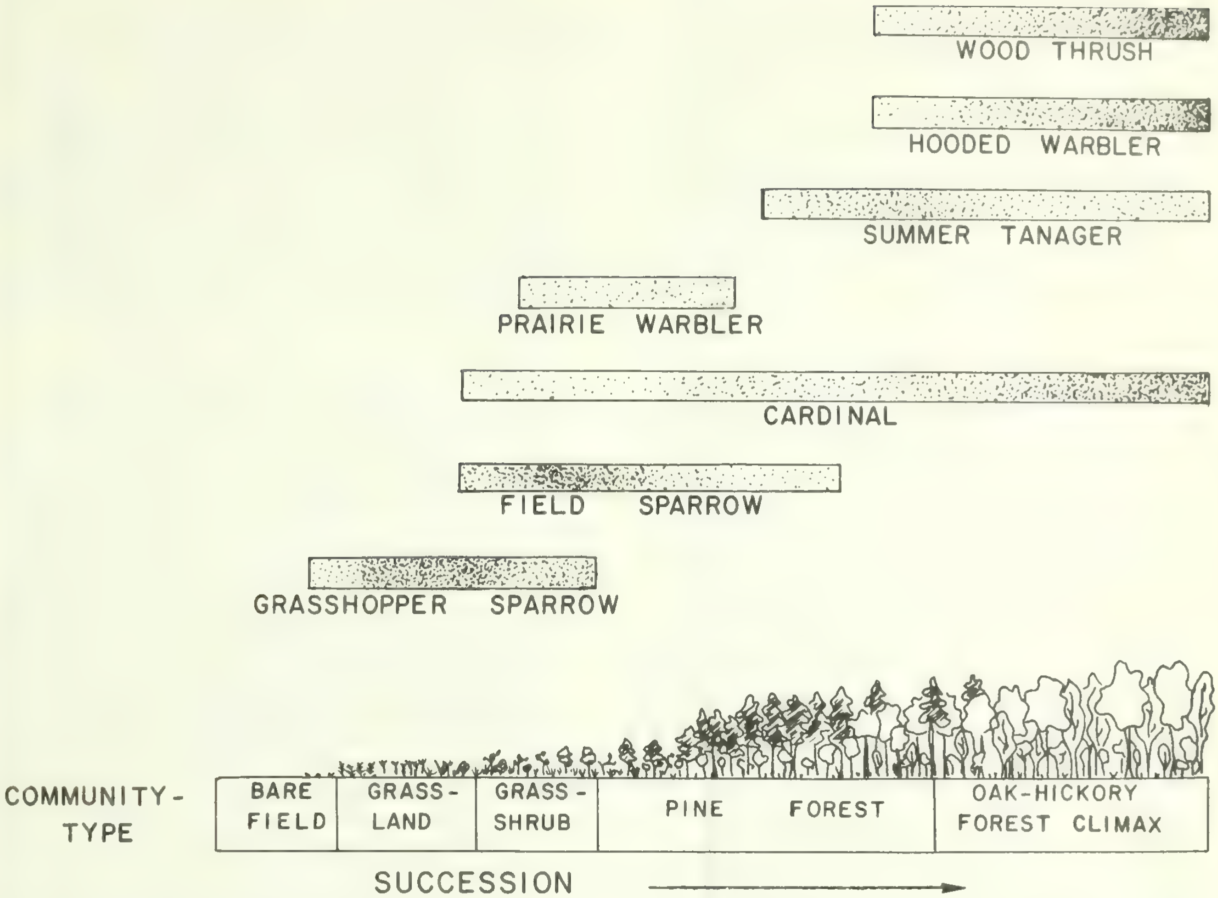


Figure 2.--The relationship between selected bird species and certain stages in old-field community succession. The differential stippling in the occurrence bars for each species indicates relative abundance (based on Johnston and Odum 1956).

height diversity (MacArthur and MacArthur 1961) and percent vegetation cover (Karr 1968, Karr and Roth 1971) do not measure horizontal patchiness of grain of the habitat (MacArthur 1968, Levins 1968). Wiens (1974) has developed a measure of heterogeneity for grasslands using the coefficient of variation, and Roth (1976) has done the same for four bird communities in the brush-grasslands of south Texas. Spatial complexity or habitat heterogeneity must be expressed in vertical and horizontal spaces, and in bird studies vegetational complexity has been measured in terms of (1) relative plant species richness, (2) horizontal foliage heterogeneity, and (3) vertical foliage profile (see Cody 1974, Tomoff 1974, Roth 1976, Pearson 1977).

Multivariate statistical analyses have been undertaken to determine the influence of a number of habitat variables on the distributions and microhabitats of entire avian communities (James 1971, Shugart and Patten 1972, Anderson and Shugart 1974, Shugart et al. 1975), and these studies also indicate that single measures of habitat complexity as predictors of bird species diversity may not be universally applicable. Shugart et al. (1975) have suggested that multivariate analysis can be a powerful tool in identifying the important habitat variables for each species in a community.

MacArthur et al. (1962) concluded that patchiness resulting from addition of layers was more important than the increased opportunity for vertical layering of birds. Karr and Roth (1971) found a sigmoid relationship which indicated that the sharpest increase in avian diversity occurs with the addition of the shrub and early tree layers and that added vegetation beyond that point produced diminishing returns. Willson (1974) also showed that the greatest addition of guilds (see Root 1967) takes place as trees appear. Roth (1976) found that while some new bird species can be absorbed in the additional patches in the transition from grassland to shrub-grassland, others may be vertically

segregated because of the additional vertical habitat space. He further suggested that an increase in stratal specialists and, consequently, horizontal overlap (see Cody 1974) occurs in the transition from shrubland to forest. Thus, according to Roth, it would appear that increased patchiness helps explain why shrublands have more species than grasslands, and by the same token, decreased patchiness may explain why forests have fewer bird species than some shrublands despite their having more vegetation layers or volume.

Trophic Complexity

Trophic complexity is a function of several factors including among others: (1) the number of trophic levels, (2) the number of species at each level, (3) the abundance of each species, and (4) the foraging strategies of each species. The complexity results from the interactions of the component species of the community, and these interactions can be characterized as being mainly predator-prey (e.g., the diversity of prey eaten) and competitive (e.g., the degree of competition with other species that is tolerated). Menge and Sutherland (1976) have examined predation and competition in relation to trophic complexity and have suggested that competition regulates the number of species in a guild only when the members of that guild actually compete, i.e., when they are near or at carrying capacity. They believe this is usually true at relatively higher trophic levels because of the absence of other controlling factors, e.g., predation. Conversely, they suggested that predation characteristically regulates the number of species present in guilds at relatively lower trophic levels. When they extended this hypothesis to between-community and between-habitat comparisons, they predicted that in communities with few trophic levels, competition will be relatively more important than predation as an overall organizing factor. As the number of trophic levels and the number of species per level increase, predation will become relatively more important as an organizing factor. Menge and Sutherland (1976) further suggested that trophic complexity is related to temporal heterogeneity in that in areas of greater temporal heterogeneity (i.e., a less stable, less predictable, and more stressful environment) there is less trophic complexity with increased competitive exclusion. With regard to the relationship between complexity and stability, May (1976) believes that a predictable (stable) environment may permit a relatively complex and delicate balanced community to exist, while an unpredictable (unstable) environment is more likely to demand a structurally simple, robust community. May (1976) pointed out that as a mathematical generality increasing complexity makes for dynamical fragility rather than robustness (but see McNaughton 1977).

According to Southwood's (1977) schema (fig. 1), trophic complexity decreases with increased adversity (sensu Whittaker 1975), and this decrease is associated more with an increase in niche width than a decrease in spatial complexity, although the latter does occur. In contrast, on the durational stability axis of Southwood's schema the relative importance of niche breadth and spatial complexity for trophic complexity is reversed.

A new measure of distance from the food source to any member of a food web has been introduced by Kercher and Shugart (1975). The measure is referred to as effective trophic position and is defined as a function of energy ingested per unit time by a population and the production of the autotrophs necessary to maintain that population. Trophic position thus defined is a generalization of the trophic-level concept capable of describing complicated food webs and based on the concept of ecological efficiency. Pimm and Lawton (1977) have recently suggested that the number of trophic levels in a community may be constrained by population dynamics and not by ecological energetics. Cohen (1977) has presented a new technique for using food webs to gain information about the minimum number of dimensions of a niche space necessary to represent, in a specific sense, the overlaps among observed trophic niche, and he concluded that within habitats of limited physical and temporal heterogeneity, the overlaps among niches along their trophic (feeding) dimensions can be represented in a one-dimensional space.

Considerable work has been done on predation and competition in birds in relation to community trophic structure. Some species differ both in food and habitat rather than either separately, and when a group of species exploits the same class of resources in a similar way in a community, the assemblage is called a guild (Root 1967). The spatial and temporal separation of some bird species has been correlated to food specialization and division of food resources (Edington and Edington 1972), and Schoener (1974) has discussed the underlying ways that similar species utilize different resources in their environment. With regard to birds, in considering the important particular dimensions in resource partitioning, habitat dimensions are more important than food-type dimensions, which are in turn more important than temporal dimensions, and as the number of species considered increases, so does the number of important dimensions in resource division.

In a thorough review of prey characteristics and the range of resources used by avian predators, Hespenheide (1975) concluded that bird species can be more closely packed in a community with

respect to food than to foraging behavior, implying that it is easier to adjust behavior (e.g., foraging zone or method) to avoid competition than to change food habits. Consequently, as species are added to the community diets will remain as wide as possible, but foraging zones should contract, resulting in habitat specialists but food generalists. Morse (1971) has provided a detailed review of how and where birds forage for food, and Schoener (1971) has examined theoretically the feeding strategies of birds and other animals with emphasis on the energetic costs of different foraging methods.

Currently, the established role of competition in structuring bird communities (Cody 1974) is being questioned (Connell 1975, Wiens 1977) because of the lack of experimental evidence in support of the idea. Connell (1975) has attempted to review the field evidence (of an experimental nature) in support of the existence of interspecific competition in birds and could find only one study (Davis 1973) indicating that one species excluded another from a particular habitat. However, this type of competitive exclusion has been proposed frequently to "explain" the within- or between-habitat or geographical segregations of certain bird species that show minimal or no overlap in their distributions (e.g., Terborgh and Weske 1975).

Niche Breadth

The concept of niche is closely integrated with spatial and trophic complexity, and it is often difficult to discuss one without making reference to the others. Before discussing the niche concept, a distinction among three aspects of the relationship of a species to environment should be reviewed (see Whittaker et al. 1973). The area of a species is the geographical range, while the habitat of a species is composed of the physical and chemical environment as well as other factors (e.g., elevation, topographic position), or of a kind of community. The niche of a species is the species' position in a community in relation to other species and is defined in terms of space, time, and functional relationships. The current theory of niche, as proposed by Levins (1968) and MacArthur (1968) and recently summarized and further developed by Vandermeer (1972) is based on the original definition of Hutchinson (1957). More recent general discussions of niche can be found in Colwell and Fuentes (1975), Pianka (1976), Whittaker and Levin (1976), and Kroes (1977).

Niche breadth, width, and size are frequently used as synonyms in the literature, and all can be thought of as the sum total of the variety of different resources exploited by a species (Pianka 1976). In the absence of any competitors or predators, the entire set of resources utilized by the organism is referred to as the fundamental, pre-interactive, precompetitive, or virtual niche (see Vandermeer 1972). Rarely if ever in nature does a species exploit its fundamental niche, but rather its activities are curtailed or modified by other species (its competitors and predators) in the community, resulting in the species' realized, post-interactive, or post-competitive niche (Vandermeer 1972). Consideration of niche breadth necessitates consideration of foraging strategies with regard to specialization and generalization (see Orians 1971, Schoener 1971, Covich 1976, Ellis et al. 1976, Norberg 1977, Pyke et al. 1977, Sih 1977). Measures of niche breadth have been provided by Simpson (1949), Horn (1966), MacArthur and Levins (1967), Colwell and Futuyma (1971), Pielou (1972), Roughgarden (1972), Vandermeer (1972), Pianka (1975), May (1975a), and Slatkin and Lande (1976). In general niche breadth increases as resource availability decreases (Schoener 1971, MacArthur 1972).

Two fundamental components of niche breadth are the "between-phenotype" and the "within-phenotype" components (Roughgarden 1972, 1974). When individuals have little or no overlap in resources used (specialists), the niche breadth of the population has a high between-phenotype component, and in contrast, when individuals exploit the entire range of resources (generalists), the niche breadth of the population has a high within-phenotype component. The subject of niche overlap is yet another central aspect of niche theory (May and MacArthur 1972, Sabbath and Jones 1973, Pianka 1974b, May 1974, McMurtrie 1976, Harner and Whitmore 1977), and as Pianka (1976) has pointed out, this subject has generated a number of concepts (e.g., competitive exclusion, character displacement, limiting similarity, species packing, maximal tolerable niche overlap, and diffuse competition). It should be mentioned, however, that equating niche overlap with competition may be on occasion a questionable practice and is often misleading (Colwell and Futuyma 1971, Connell 1975, Pianka 1976, Wiens 1977). Competitive interactions in communities and their bases have been thoroughly discussed recently by Connell (1975), Pianka (1976), Levine (1976), deJong (1976), and Wiens (1977).

There has been considerable emphasis on niche theory in the work on avian communities. Cody (1968, 1974) has carefully examined niche theory in his work on the role of competition in the structuring of bird communities, and he has given detailed attention to niche breadth and overlap in his treatment. Niche overlap has also been studied in feeding assemblages of birds in New Guinea (Terborgh and Diamond 1970), in the avifaunas of Australian islands (Abbott 1975), in passerine birds in the

British West Indies (Ricklefs and Cox 1977), and in passerines in Swedish coniferous woodlands (Ulfstrand 1977). Alerstam et al. (1974) have studied the niche differentiation during winter in woodland birds in southern Sweden and on the nearby island of Gotland.

Several studies have shown that bird species broaden their niches on islands by changing their vertical foraging distributions, but seldom changing their foraging behavior (Crowell 1962, Diamond 1970, Yeaton and Cody 1974, Diamond and Marshall 1977). The origin of differences in community structure, such as those between different islands of the same archipelago, between different localities on the same island, between different adjacent habitats, and between different biogeographical regions have been reviewed by Diamond (1975). His hypothesis is that through diffuse competition, the component species of a community are selected and coadjusted in their niches and abundances so as to fit with each other and to resist invaders. The relationship between niche breadth and the amount of morphological variation within and between species has been examined by a number of investigators (Grant 1968, 1971; Willson 1969; McNaughton and Wolf 1970; Keast 1972; Rothstein 1973; Hespenheide 1975; Karr and James 1975; Willson et al. 1975), and although the results suggest that competitive displacement may be a particularly important determinant of avian community structure, such comparisons may provide results that are misleading (Wilson 1975).

Hespenheide (1975) has examined resource characteristics and consumer niche width in birds and has concluded that coexistence depends on maintaining minimum differences between species and, for strategic reasons, space and behavior are more easily divided than food directly in competitive situations. The data for foliage-gleaning species and for birds in general support this conclusion.

Standing Crop and Turnover Rate

Both standing crop (biomass) and turnover rate (productivity divided by biomass) vary during succession and as a result of the adversity of the environment (see fig. 1). Standing crop and productivity increase throughout successional stages, providing for increased spatial complexity (Whittaker 1975), but productivity frequently, but not invariably, falls in terrestrial communities as the climax is reached (Margalef 1969) so that turnover rate invariably falls (Watt 1971). Holt and Woodwell (in Whittaker 1975: 175) have examined secondary succession in the oak-pine forests of Long Island, New York, and have found in the first year of succession, net productivity is low and increases to a fairly stable level in the meadow stage. Through the shrub and young tree stage, net productivity increases more steeply in the young oak-pine forest, at 45 to 55 years, and this level stabilizes and persists in the mature forest. The growth of the forest can also be expressed by the biomass accumulation ratio (the ratio of biomass to annual net productivity), and these ratios increase from about 1.0 in the annual stage, to 2-4 in the meadow stage, to 4-7 in the shrub stage, to 10 in the 55-year forest and probably 25-35 in the mature forest (Holt and Woodwell in Whittaker 1975:175).

Connell and Orias (1964) have suggested that greater plant productivity during succession should support greater diversity, everything else being equal. Productivity of the community should be positively correlated with the closeness of species packing (MacArthur 1971). Although rigorous data are scarce, there is nonetheless some evidence in support of this idea. Bird censuses in small areas of 4-6 hectares of nearly uniform habitat show that the number of species generally increases with the productivity of the habitat. If one compares the mean net primary productivity per unit area (dry $g/m^2/yr$) of Whittaker (1975:226) with measurements of species diversity (Tramer 1969) in nine types of communities, a pattern emerges that suggests that the more productive forest communities have the higher number of species (Table 2). Cody (1974:127) has also shown that the number of bird species and species diversity are, in part, correlated with community productivity.

Glutz von Holtzheim (1962), working in Switzerland on bird communities, suggested that greater production in a forest habitat allows it to support denser populations. Karr (1975) has also suggested that differences in productivity may be important in determining the number of individuals (not the number of species) that can breed in an area (but see Cody 1974:127-128). Several studies have examined changes in bird standing crop during succession and in different communities. Karr (1971) found a general increase in bird standing crop and existence energy as the ecological age of abandoned strip mine areas in Illinois increased. Similar findings have been reported by Sturges et al. (1974) and Shugart et al. (1975). In these studies there is general agreement that bird biomass and bird density increase in older communities, but when bird biomass is plotted on bird density, the slopes of the lines are often different (see Wiens 1975:238). Shugart et al. (1975) found that the general patterns of bird standing crop in the successional communities studied by Shugart and James (1973) was the same as the pattern of bird density, indicating that the average size of breeding birds did not fluctuate

Table 2.--Net Primary Production (Annual Basis) of Several Communities and Bird Species and Diversity*

Community Type	H'	S	Net primary productivity per unit area ($g/m^2/yr$)†
Marshes	1.79±0.34	6.33±1.32	2000
Grasslands	1.93±0.24	5.74±1.00	600
Shrublands	3.14±0.16	14.08±2.31	700
Deserts	3.25±0.60	14.17±5.68	90
Coniferous forests	3.53±0.14	17.43±1.92	1300
Upland deciduous forests	3.82±0.08	20.94±1.34	1200
Mixed forests	3.92±0.14	21.87±2.76	1200
Floodplain deciduous forests	4.07±0.16	24.22±2.84	2000
Tropical woodlands	5.23±0.24	55.14±11.24	2200

*Productivity information after Whittaker and Likens in Lieth and Whittaker, 1975:224; bird information after Tramer, 1969.

†Units are dry grams of organic matter per meter square.

widely through the successional sequence. However, they did note that in ecotonal stages the size of birds tended to be larger on the average, and in the mature forests the mean size appeared to be somewhat smaller. Wiens (1975), in comparing different coniferous forest communities of North America, found trends in total biomass of birds similar to densities of birds, although the magnitude of fluctuation in biomass was more variable. In all coniferous forest types biomass increase occurs at different rates. The rate of increase is most rapid in northeastern coniferous forests and Sierra Nevada avifaunas and markedly less steep in northwestern, northern, and southeastern coniferous forests. This indicates that the increase in density in these latter regions is through the addition of relatively small-sized individuals to the avifauna, while comparable incremental increases in avian density in northeastern and Sierra Nevada forests involve the addition of individuals of larger mean size (Wiens 1975). Moreover, in northeastern coniferous forests, immature stands, supporting the same number of individuals as comparable mature forest stands, contain more avian biomass; hence the mean size of individual birds is greater in the immature stands. McNaughton and Wolf (1973:346-348) have done a similar analysis on the data of Johnston and Odum (1956), and the results are in agreement with the notion that during successional changes in the avifauna of a community, early stages support fewer species and individuals and less avian biomass than older stages, and the species tend on the average to be larger and ecologically more dominant. Consequently, during succession the birds that invade tend to be smaller on the average than the species they replace. Breeding bird density and bird standing crop in coniferous forests and in grassland habitats when compared show some comparable results (Wiens 1975, Wiens and Dyer 1975).

While standing crop of breeding birds in coniferous forests average 2 to 3 times that in grasslands, energy flow is nearly 10 times as great in the coniferous forest. This probably reflects the greater degree of dominance of extremely small species (forms which have relatively high energy demands per unit of body weight) in comparison to the larger species common in grasslands (Wiens 1975). Faaborg (1977) has examined the occurrence of nonpasserines in terrestrial avian communities with an emphasis on metabolic rates, activity levels, and resource availability. He concluded that the metabolically more conservative nonpasserines can support larger populations on a given amount of rare resource and expend less energy looking for these rarer resources. The differential occurrence of such resources in the tropics and in temperate areas probably explains why more nonpasserines occur in the tropics than in temperate communities.

Wiens (1975) and Wiens and Nussbaum (1975) have reported that the avifaunas of coniferous forests in North America during the breeding season from 1 April to 7 October have an energy demand ranging from 10.7 $kcal/m^2$/season in the dry, hot forests to 20.8 $kcal/m^2$/season in moist, transitional forests. These figures generated by simulation models are in general agreement with the calculated energy demand of 11.3 $kcal/m^2$/year by the avifauna of an oak-hornbeam forest in southern Poland (Weiner and Glowacinski 1975). In the latter study, the authors pointed out that approximately 50% of the annual energy demand occurs during the breeding season.

Salt (1957) proposed that the ratio of consuming biomass to standing crop biomass of a community (CB/SCB) may be a measure of efficiency in food utilization in avian communities, because communities dominated by large species that require less energy per gram of body weight exhibit a greater discrepancy between consuming and standing crop biomass. A number of authors have concluded that there is an increase in community energetic efficiency (measured by the CB/SCB ratio) as succession proceeds towards the climax (Salt 1957, Karr 1968, Kilgore 1971, Wiens 1975), but McNaughton and Wolf (1973: 348) have noted that avian production efficiencies decline as succession proceeds in abandoned agricultural fields in the southeastern United States. Ecological efficiencies relating a trophic level to the preceding level tend to increase up the pyramid of productivity, but net growth efficiencies usually decrease, because the percentage of food energy respired tends to rise along food chains. Consequently, net of production efficiencies need not increase up the pyramid; they may in fact decline (Whittaker 1975:217).

The ratio of net productivity to biomass (P/B) or turnover rate decreases from grasslands to forest communities. Thus the time it takes to replace the peak biomass completely at a given successional stage increases as succession progresses. How do bird communities respond to the different turnover rates of vegetation during succession? Shugart and Hett (1973) found that the bird species composition of a community changed more rapidly than the plant species composition although the pattern of change was the same between plants and birds. Glowacinski and Jarvinen (1975) examined the turnover rate during secondary succession in forest bird communities in oak-hornbeam forest in Poland and in Finnish coniferous of spruce and pine. They found that the shrub phase is characterized by rapid changes in the bird community and its rate of change, while the forest proper has a slowly changing avian community and the rate of turnover changes relatively slowly.

Species Diversity and Abundance

The simplest community attributes that can be measured are the number and relative abundances of species in an area. It is not practical to study all the species of a given community, so that most workers have concentrated on a portion of a community or taxocene (e.g., birds, lizards, trees, ants). The term "taxocene" (Hutchinson 1967) means all the members of any taxonomic group of a higher level than a species. The emphasis on species composition and abundance in communities during the last half century has resulted in a great number of measurements of species diversity for various communities (Williams 1964). These quantitative indices show the relation between community structure not only in number of species but also in the relative number of individuals of each species. There are a number of different indices of species diversity, and each varies in what it shows (e.g., Williams 1964; Lloyd and Ghelardi 1964; Pielou 1966, 1975; Dickman 1968; Lloyd, Zar, and Karr 1968; Hurlbert 1971; Whittaker 1972; DeBenedictis 1973; Peet 1974; Hair 1978).

The Shannon-Wiener function and the Simpson index are two of the most commonly used measures of species diversity. Ideally the Shannon-Wiener measure should be used only on random samples drawn from a large community in which the total number of species is known. The Shannon-Wiener measure combines two components of diversity: (1) number of species and (2) equitability or evenness of allotment of individuals among the species. In Simpson's index, relatively little weight is given to the common species. Recently the utility of diversity indices has been questioned in ecological studies (Peet 1975). The measures of species abundance and diversity have been reviewed analytically by May (1975b), and May (1976:158) has recently argued for describing the community by its full distribution of species relative abundance, and not trying to condense information into a single diversity index which may mislead and may obscure valuable information on the few uncommon species in the community.

It is important to distinguish between species diversity measurements in a single natural community and in a large heterogeneous region. Whittaker (1960) has defined three categories of species diversity patterns: (1) alpha diversity--the diversity in a sample drawn from a single community, often referred to as within-habitat diversity; (2) beta diversity--the diversity that expresses the rate of species turnover between habitats, sometimes called between-habitat diversity; and (3) gamma diversity--the total diversity found in all the available habitats in a fairly large geographical area. Additional considerations of these categories can be found in Whittaker (1972), Allan (1975), Tramer (1974a), and Pielou (1975).

Diversity Gradients

One of the most conspicuous aspects of the geographical patterns of bird species distribution is the gradient in numbers of breeding bird species from the poles to the equator (Dobzhansky 1950, MacArthur 1972:199, Welty 1975:413). More bird species occur in

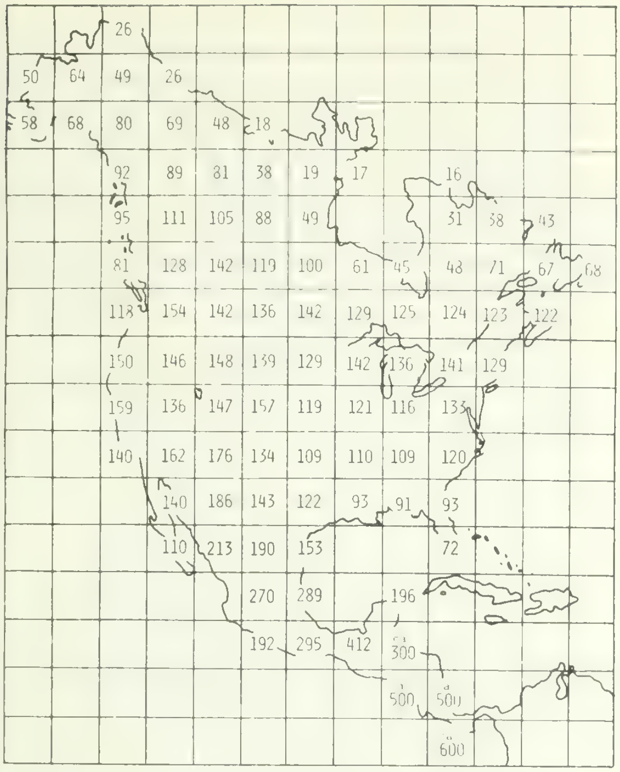


Figure 3.--The numbers of land bird species breeding in quadrants of 500 km per side in different parts of North and Central America (after MacArthur 1969 and MacArthur and Wilson 1967).

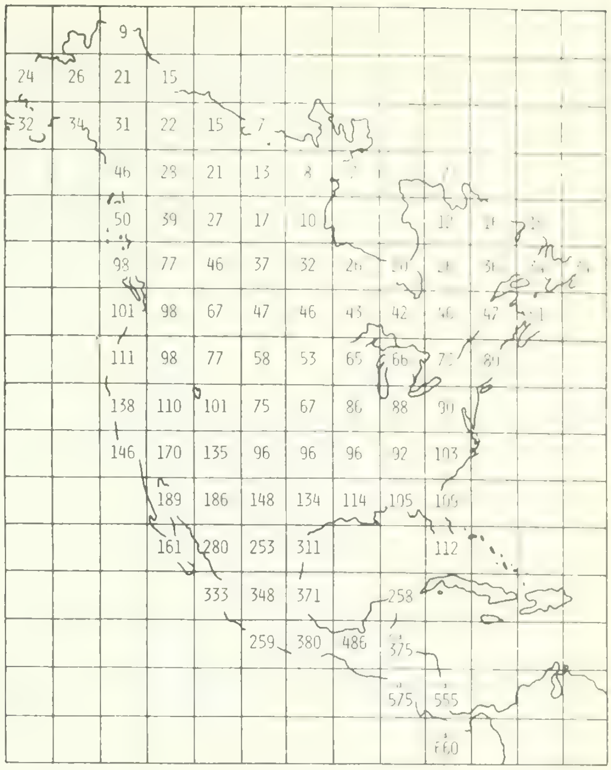
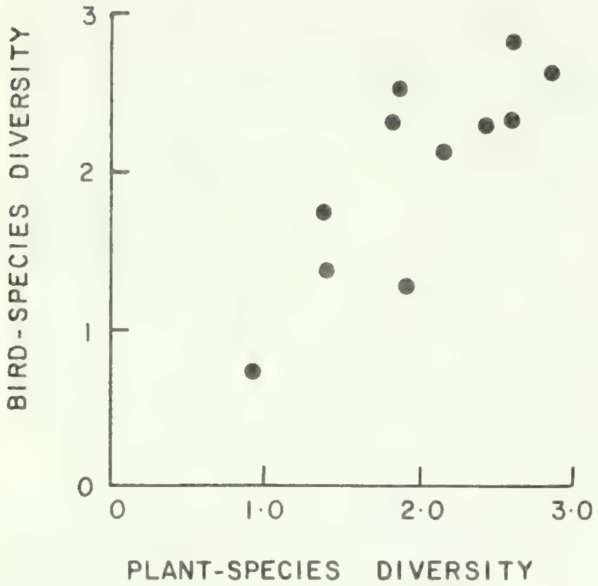


Figure 4.--The numbers of land bird species wintering in quadrants of 500 km per side in different parts of North and Central America (after Tramer 1974a).

tropical communities than in temperate and arctic communities, and this pattern is found in most other terrestrial taxa of large enough size (Klopfer and MacArthur 1960, 1961; MacArthur and MacArthur 1961; MacArthur et al. 1966; MacArthur 1969; Orians 1969; Karr 1971; Karr and Roth 1971; Schoener 1971). The numbers of breeding land bird species in different geographical sectors and communities of North America have been computed (MacArthur 1965, 1969, 1972; MacArthur and Wilson 1967; Cook 1969; Tramer 1969, 1974a; Peterson 1975), and as Tramer (1974a) shows, during the breeding season the alpha diversity for bird species does not change significantly from 45°N to 25°N, but from 25°N southward, alpha diversity increases as one moves toward the equator. Gamma diversity of breeding birds, on the other hand, differs in both eastern and western North America. In the East, gamma diversity decreases from 45°N southward to southern Florida and the northern coast of the Gulf of Mexico. In the West, gamma diversity increases all the way to the equator (fig. 3). As can be seen in figure 4, during the winter the numbers of land bird species in different communities and regions of North America have also been examined (Bock and Lepthien 1974; Tramer 1974a, 1974b), and in winter both the alpha diversity and gamma diversity of bird species increase southward (Tramer 1974a).

Tropical mountain-top communities have fewer bird species than would be expected on the basis of geographical latitude (Orians 1969, Kikkawa and Williams 1971, Diamond 1973), and although these communities have mean annual temperatures and short heights of trees more typical of temperate zones, there is no winter. Even though fewer species occur in mountain communities at higher altitudes, Terborgh (1971) has pointed out that in Peru an altitudinal transect showed more forest bird species than the entire eastern United States.

Certain communities have a higher avian species diversity than others (e.g., Margalef 1963, 1968; Recher 1969; Tramer 1969; Karr and Roth 1971; Cody 1974; Rov 1975; Reese 1976), and bird species diversity usually increases during succession (e.g., Kricher 1973, Shugart and James 1973, Hamilton and Noble 1975). What are the factors responsible for higher species diversities in communities as one moves toward the equator, and why do certain communities have higher species diversity indices than others?



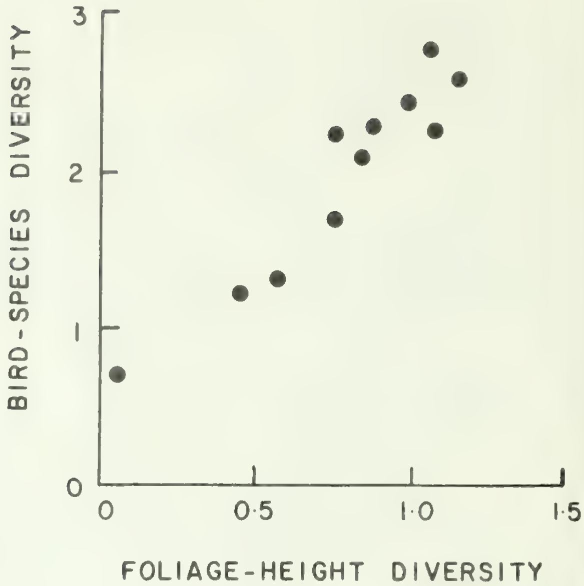


Figure 5.--Bird species diversity in deciduous forest plots of eastern United States in relation to (A) plant species diversity and (B) vegetative structure (after MacArthur and MacArthur 1961).

Determinants and Correlates of Diversity

In an effort to determine what factors account for species diversity in selected forest types, MacArthur and MacArthur (1961) found that from the layering of the vegetation alone they could predict the number of breeding bird species in temperate deciduous forests and that further knowledge of the number of plant species did not improve the understanding (fig. 5A and 5B). They concluded that height profile of foliage density in the layers 0-2 feet, 2-25 feet, and greater than 25 feet is important in determining bird species diversity, and they felt that these three layers correspond to different configurations of foliage--herbs, shrubs, and trees over 25 feet tall--in five acres of habitat (see MacArthur and Horn 1969). The height profile of foliage density is in fact a major component of the floristic community that allows birds to specialize on a particular part of the habitat (MacArthur 1964, Karr and Roth 1971, Cody 1975, Roth 1976).

That birds restrict their activities to different levels within a forest is well known. Even though birds are highly motile they are nonetheless characteristic inhabitants of a particular forest stratum, or even a particular level within a given stratum. Colquhoun and Morley (1943) in a paper on the relative stratal abundance of 12 species of birds in Bagley Wood in England found that the majority of species utilized several strata with a particular stratum of abundance for each kind of bird. In an almost pure stand of Quercus robur, they identified five strata utilized by the birds: (1) upper canopy (above 35 feet), (2) tree (15 to 35 feet), (3) shrub (4 to 15 feet), (4) herb (3 inches to 4 feet), and (5) ground. Similarly, Kendeigh (1945) found breeding warblers generally stratified (or even substratified) in a sugar maple-beech-hemlock forest near Albany, New York, and concluded that diversification in niche requirements reduced interspecific competition and permitted a greater and more varied population to inhabit an area. Gibb (1954) studied coexistence in the Parids of Britain and demonstrated that different species fed in different strata when several occurred together in the same habitat. In structurally simpler habitats than forests (e.g., grasslands, fields, and marshes), the opportunities for within-habitat segregation are less, and there are fewer bird species per unit area (Cody 1968, Wiens 1969). Cody (1974:29) pointed out that in habitats taller than 3 feet vertical stratification is the single most important factor in the segregation of species' feeding activities.

Orians (1969) found that the number of bird species in Costa Rica was not correlated with the number of tree species but was closely associated with foliage height diversity. The same is true for the southeastern

portion of Australia near Sydney (Recher 1969). In Puerto Rico, MacArthur et al. (1966) found vertical foraging ranges expanded, and species diversity was predictable when only two layers of vegetational height profiles were considered. Similarly, the vertical foraging range of birds was found to be expanded on species-poor islands in Panama Bay in comparison to mainland Panama (MacArthur et al. 1972). Karr (1971) likewise found that vertical foraging ranges in Illinois were more expanded in comparison to Panama, thus documenting the narrower vertical foraging ranges of tropical species. Pronounced vertical stratification has also been found in a dry forest in Peru, and moreover the vertical foraging ranges of many of the species shift as a function of time of day (Pearson 1971).

Although the number of species and their abundance can be predicted accurately on the basis of height profiles of foliage density, MacArthur (1964) failed to predict just what bird species would be present in the complex habitats on the slopes of the Chiricahua Mountains of southeastern Arizona. Additional findings do not support MacArthur's foliage profile hypothesis. Balda (1969) failed to find a significant correlation between bird species diversity and foliage profiles in ponderosa pine and oak-juniper forests in Arizona. Although juniper was the most abundant tree in the oak-juniper forests and had a good fit for bird use according to the height distribution of the foliage, juniper was sparsely used by the birds. Instead the birds used the two species of oak more heavily, and all parts of a tree were used by the several bird species. Total bird use of Douglas fir foliage by height class was not correlated because there was a large proportion of low foliage that was underused while the upper heights were overused. Consequently, the very few tall Douglas firs in the area were used greatly out of proportion to their availability. Marshall (1957) has earlier reported similar findings in his studies of bird utilization of pine-oak habitat in Arizona. In the latter two cases the birds were probably showing within-habitat segregation (e.g., (a) different parts of trees or bushes, (b) different species of plants, or (c) different sections of the habitat characterized by overall differences in vegetation structure) (Cody 1974:23).

Tomoff (1974) related bird species diversity to some measures of vegetative complexity (plant densities, foliage height diversity, and physiognomic coverage diversity) and found that the physiognomic coverage diversity (life forms divided into categories) was significantly correlated with bird species diversity. Tomoff (1974) concluded that plant species diversity may be highly important to desert breeding birds because each plant species may have peculiar properties which are needed by the birds for breeding. Additional shortcomings of using only foliage height diversity to predict bird species diversity can be found in Balda (1975), Reese (1976), Roth (1976), and Pearson (1977).

Temporal Aspects

Most studies of bird species diversity in various communities have concentrated on breeding birds, and the seasonal aspects of avian diversity in the community have been largely ignored. Stewart et al. (1952) found that the composition of the avifauna changed throughout the year in Maryland with the greatest number of species occurring in the spring and the greatest number of individuals occurring in the fall. Kricher (1972) and Holmes and Sturges (1975), working in the New Jersey piedmont and in New Hampshire, respectively, noted that bird species diversity decreased from summer to winter as a result of fall migration. Dickson (1974) found that species diversity in a bottomland woods in Louisiana increased from summer to winter, indicating that there were more overwintering migrants in the area than breeding migrants. Cody (1974:154), working in the Santa Monica Mountains in southern California, and Reese (1976), working in the piedmont of South Carolina, found that bird species diversity increased from summer to winter in certain habitats but remained the same or decreased slightly in other habitats. These results based largely on alpha diversity measurements are in general agreement with the summer and winter gamma diversity measurements of Tramer (1974a). Clearly, considerably more work is needed on the seasonal dynamics of avian community ecology if we are to gain a better understanding of how avian communities are structured and organized.

EPILOGUE

In this presentation I have attempted to present an up-to-date overview of avian community ecology. My overview is fairly representative but not exhaustive. Ecology as a whole and avian ecology specifically is in the process of undergoing major revisions and reassessments (see Foin and Jain 1977). A few years ago complexity of the community was thought to impart stability to the community, but rather recently we have increasingly appreciated that stability (e.g., climatic stability) is a requisite for community complexity, and when stability is not present complexity cannot be achieved. Less complex communities cope better

with adverse and unpredictable environments. Goodman (1975) has recently critically reviewed the diversity-stability relationships in ecology and concluded that there is no simple relationship between the two. Competition has long been the cornerstone of niche theory, but lately some serious doubts have emerged regarding the role of competition in shaping diverse communities, and predation is being examined more closely. Likewise, many avian ecologists have been content with accepting foliage height diversity as the best predictor of bird species diversity, but several relatively recent studies have cautioned that foliage height diversity must be considered but one of many "dimensions" and factors dictating bird species diversity; bird behavior and climatic factors are receiving more attention. Avian communities show seasonally rhythmic changes, but there has been little appreciation for this fact as the preponderance of breeding season studies attests. We have much to learn of the energetic efficiencies of the avifauna in a community throughout the year and from year to year during succession. In depth experimental (manipulative) field studies of avian communities are needed if we are to make meaningful statements about man's influence on bird communities. We do have some knowledge of the structure and function of avian communities, but clearly much, much more remains to be done. Theory abounds and is very much in vogue, but carefully detailed empirical findings are needed most.

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Tuesday Afternoon, January 24

Effects of Management Practices on Nongame Birds

Moderator: Fred Kinard
Westvaco Corporation

Effects of Management Practices on Nongame Bird Habitat in Longleaf-Slash Pine Forests

Gene W. Wood and Lawrence J. Niles[1/]

Abstract.--Increase in numbers of habitat niches that develop with increasing stand complexity is important to raising the species richness and abundance of non-game birds in longleaf and slash pine forests. Some silvicultural practices decrease complexity while others increase it. Practices which lead to eradication of the understory, destruction of dead trees and generally promote monoculture appear to be deleterious to non-game bird populations.

INTRODUCTION

The approach of this paper will be largely a theoretical discussion of the response of non-game bird populations to habitat changes caused by silvicultural practices in longleaf (Pinus palustris) and slash pine (P. elliottii) forests. Non-game birds will be discussed collectively with very little emphasis placed on individual species. This is necessitated by the dearth of published literature on non-game bird response to silvicultural practices in the southern pine forests.

LONGLEAF-SLASH PINE TYPE

Longleaf pine occurs naturally in portions of 9 southeastern states in a climatic zone characterized by long, hot summers and mild winters. The main longleaf pine belt is found on the Atlantic and Gulf Coastal Plain, though it extends into the Piedmont and Appalachian borders. Soils are characteristically sandy in texture, low in organic matter, have good to excessive drainage, and are low in fertility. (USDA 1965:384-385)

Slash pine, in general, can be grown wherever longleaf grows although its natural range is considerably more restricted. The natural range extends from southern South Carolina to central Florida and southeastern Louisiana although it has been planted as far north as North Carolina and west to East Texas. Soils are typically sandy and range in drainage from well drained to poorly drained. The wet soils of pond margins are most productive. (USDA 1965:458-459)

There are 18.3 million acres of land in the longleaf-slash pine type. Five percent of this land is in natural forest and five percent in other public holdings. The forest industry owns 33 percent of the longleaf-slash pine type with 57 percent in other private holdings. (USDA 1973:304-305)

Within the geographical range of the longleaf-slash pine type there are 68 species of birds that are year round residents, 40 of which are associated with pine forest habitat. There are 106 summer residents and 112 winter residents of which 49 and 54 respectively are associated with pine habitat. (Bent 1937, 1938, 1939, 1940, 1942, 1946, 1948, 1949, 1950, 1953, 1968; Robbins et al. 1966, Harrison 1975, Bull and Farrand 1977)

PRINCIPLES

The influence of silvicultural practices on wildlife is based on the principles of the relationships of plant community complexity and productivity to habitat niche variety and carrying capacity. The habitat niche is the assimilation of environmental components necessary for a species to maintain and sustain life. The habitat is a more inclusive term and refers to the general environment and plant associations within which a species is found. In this paper the habitat is the longleaf-slash pine forest type. In principle, habitat niche variety is directly related to habitat complexity and is the deter-

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minant of the variety of animal species that can be accommodated. Simple plant communities, such as an even-aged monoculture, will not support as large a number of bird species as a more heterogenous community. The habitat niches simply are not there. In the forest, a tract of land with a wide variety of stand conditions can be depended upon to provide the habitat niches for a wide variety of bird species. Similarly, within a given forest stand vertical structure complexity will determine habitat niche availability with the most structurally complex supporting the widest array of bird species.

Carrying capacity is the number of individuals of a species that can be accommodated in a given habitat niche. In general, in natural communities, the size of the array of niches and their respective carrying capacities are expressions of site productivity potential. The potentially most productive sites in terms of dry matter productivity will usually support the most structurally complex and species rich communities. In addition to the wide variety of bird species that can be supported, relatively large numbers of individuals within these species will occur in these communities. This phenomenon in forest communities can be changed by silvicultural procedures. The implementation of procedures that channel nutrients, water, and energy into single plant species tend to greatly reduce natural complexity. This decreases the size of the array of niches and consequently species diversity, an expression of numbers of species and individuals within species, of non-game birds.

Data that support these principles with respect to non-game bird populations have been published by Saunders (1936), Kendeigh (1948), Odum (1950), Johnston and Odum (1956), Bond (1957), MacArthur and MacArthur (1961), MacArthur et al. (1962), Karr (1968), Davis and Savidge (1971), Shugart and James (1973), Kritcher (1973), and Roth (1976).

COMPLEXITY WITHIN AND AMONG STANDS

As previously stated a wide variety of habitat niches may be available in a forest that has a wide variety of stand conditions, i.e., successional stages and compositions of species. The complexity or heterogeneity in this area is referred to as beta-diversity. The forest manager's ability to create a forest mosaic that will support a species rich and diverse non-game bird population will depend on his ability to govern stand size, stand structure, and juxtaposition of stands.

The primary unit that the forester deals with is the stand, which is itself a plant community. The silvicultural treatments applied to the stand will determine its individual complexity or heterogeneity or alpha diversity. In addition, the natural changes in stand complexity concurrent with natural development are important to recognize in order to know what portions of the forest are providing the habitat niches and various levels of carrying capacity for given birds. For these reasons this paper will be confined to the influence of silvicultural treatments on stand complexity as it relates to raising and lowering the number of habitat niches.

REGENERATION CUTTING

The time of the final harvest of longleaf and slash pine stands is also the time of the beginning of the new stand. Three general methods of harvest may be used in these timber types and the method used will determine the nature of non-game bird habitat. The methods are seedtree, shelterwood, and clearcutting followed by planting. Each of these methods is preceded by prescribed burning for seedbed preparation. At this point there are two habitat parameters in which changes wrought by the silvicultural treatment will be reflected in bird response. These are the conditions of the understory and the existence of dead trees left standing.

Generally, seedtree and shelterwood cutting will lower the carrying capacity for overstory species but may raise it for understory birds. In these methods, prescribed burning will usually be carried out in the fall of good seed years and followed by logging. While much of the aerial portion of the understory may be killed by the fire most of the woody stems will remain standing. Enhancement of the non-game bird population may stem from several causes. First the destruction of the litter layer exposes quantities of seed that normally would have gone undetected by birds foraging in the winter habitat. Flocks of wintering sparrows, Robbins and Dark-eyed Juncos will frequently be seen taking advantage of this forage resource. In addition, where the woody understory is sparse, small mammals will be made more vulnerable to birds of prey. Sharp-shinned, Sparrow, Red-tailed, Coopers and Red-shouldered hawks may be seen hunting on recent burns. Second, the stand understory will make significant recovery in the first growing season following treatment. Many of the hardwood seedlings, shrubs and perennial herbs will resprout the following spring. Spring

nesting cover will in large part be missing, but foraging opportunities should be relatively abundant by mid-growing season.

Seedtree and shelterwood methods have minimum adverse impact on the bird population. The degree of impact will depend upon the amount of residual overstory left standing and the length of time before the residual is removed. Because of the heavier seed of longleaf, more residuals are required to insure adequate distribution of seedlings than is the case in slash. Walker (1962) recommended 10 to 12 seedtrees per acre to be left in a seedtree cut for longleaf or alternately 40 trees per acre in a modified shelterwood with residuals being removed in about two years. Croker and Boyer (1975) recommended 30 sq. ft. of basal area be left of seedbearers in a longleaf shelterwood. In this interim period from time of the regeneration cut to the time of the removal of the residuals the habitat is generally productive following either method but mostly for the shelterwood. Bennett (1965) recommended 4 to 6 seedtrees per acre in seedtree cuts and a basal area of 20 to 30 square feet in a shelterwood for slash pine with residuals being removed about one year after regeneration establishment. The existence of a broken overstory and a developing understory of seedlings, shrubs, and herbs is a complex habitat and one which has considerable niche diversity. Carrying capacity for overstory bird species will be governed by the heaviness of the cut while carrying capacity for understory bird species will be regulated by the vegetation response which in turn will be regulated by nutrient and moisture availability. Pine Warblers will be abundant in these stands in all seasons of the year. Once the understory develops Yellowthroats will also be common. Spring and summer birds may include Summer Tanager, Great-crested Flycatcher, Prairie Warbler, and Blue Grosbeak.

Clearcutting followed by intensive site preparation and planting has the most dramatic impact of the harvest and regeneration techniques on forest bird habitat. It is a technique employed in slash pine where the stand will be managed on a short rotation usually not exceeding 35 years. It may be employed in longleaf stands on very productive sites in the heart of the longleaf range along the Gulf Coast from Louisiana to western Florida.

This procedure essentially eliminates bird habitat for a short period of time. The overstory is completely removed in the harvest and the remaining vegetation destroyed during site preparation. Chopping, disking, burning, and bulldozing slashings, stumps and roots into windrows leaves essentially a bare soil surface with little forage and no protective cover. The community is in its simplest structure and niche diversity and space are at a minimum. The windrows created ameliorate the situation to some extent. They will contain some cover for shelter and escape. In addition, since the soil in the windrows is almost entirely top soil and contains large quantities of seed, dense vegetation will develop in the first growing season after treatment and offer both foraging and escape cover.

Clearcutting with natural regeneration has a much less destructive effect. In this case prescribed fire is used to prepare the seedbed before harvesting. After seedfall, the stand is harvested and seed germination occurs shortly thereafter. In this treatment there is drastic impact on birds that include the overstory as part of their niche but understory species may be enhanced.

STAND DEVELOPMENT

Johnson et al. (1974) recognized 5 stages of development of young southern pine stands that might be reflected in non-game bird population response. These were: (1) the devegetated area produced by site preparation, (2) seedling stage, (3) sapling or brush stage, (4) crown closure to an age of about 15 years, and (5) 15 years to the end of the rotation. Length of time in each of these stages will of course be affected by site conditions, method of planting, species treatments such as fertilization, precommercial thinning, and prescribed burning.

As previously pointed out, the site preparation stage has minimum capacity to support bird populations, but in the seedling stage the habitat begins to recover. Stransky et al. (1976) reported that a loblolly pine regeneration area that had been chopped and burned was rich in species of seed producing grasses, composites, legumes, vines and shrubs at the end of the first growing season following treatment. This same type of response could be expected on slash pine regeneration sites where the soils are moderately well drained. Longleaf regeneration sites are typically drier and the vegetation response will usually be less rapid.

The nature of the habitat in the seedling stage will be determined to some extent by the method of regeneration. In addition the stocking rates will influence the length of time until crown closure and the severity of competition with herbs, shrubs, vines and hardwood seedlings which add to habitat complexity. Under favorable conditions dense stands of regeneration can be established by clearcutting, seedtree, shelterwood and direct seeding methods. The removal of overstory residuals in the seedtree and shelterwood method will thin these stands to some extent by mechanical damage incurred during logging and provide growing space for plants other than pines. In these stands being naturally regenerated usually only prescribed burning will have been done for site preparation and the mix of herbs, shrubs and hardwood seedlings with the pine seedlings will create a substantially complex habitat. In direct seeding, however, the site will usually have been devegetated and the seedbed prepared by drastic disturbance. In this situation, particularly where seedling establishment is highly successful, the habitat will rapidly approach the minimum complexity of a monoculture.

Natural regeneration and direct seeding are more common in longleaf pine than in slash. Slash pine is most frequently regenerated by planting. Again the rate of seedling stocking will be important particularly for determining the character of the sapling or brush stage. The U. S. Forest Service Wildlife Habitat Management Handbook for the Southern Region (USDA 1971) recommends planting on a 10 ft. x 10 ft. or 10 ft. x 12 ft. spacing to encourage understory development. Hawley (1965) presented data showing that basal area in slash pine planted on a 6 ft. x 6 ft. spacing at age 9 years exceeded the 10 ft. x 10 ft. spacing by a factor of 1.6. This would be quite an expensive trade-off in timber value for bird habitat. Possibly more reasonable initial spacing might be 6 ft. x 8 ft. or 5 ft. x 10 ft. where Hawley (op. cit.) reported basal areas to be 93 percent and 83 percent respectively of the 6 ft. x 6 ft. spacing and still provide space for understory development.

The early seedling stage in both longleaf and slash pine may provide important habitat for grassland users especially on site prepared areas. Within the range of these timber types, summer use will probably be minimal. Summer temperatures on these areas are extremely high and the vegetative cover that can serve as shelter is largely missing. Some migrants and winter flocks of sparrows and juncos will use these sites heavily, however.

The length of time that the stand will be in the seedling stage will differ greatly between longleaf and slash. Slash pine may be in the sapling stage in 3 to 4 years and the stand may close by 5 to 6 years of age. Longleaf on the other hand may remain in the seedling stage up to 10 years depending upon the severity of brown spot needle blight. During this time the stand may be repeatedly prescribed burned on a 3-year schedule, the impact of which will be to maintain the stand in an "old field" type of succession. Grassland and shrub vegetation users will be accommodated in this situation.

Fire cannot be used in the seedling or sapling stage of slash pine development until the trees are 10 to 15 feet high (Cooper 1965). Neither can it be used in longleaf pine after leader growth begins until the stems are at least 10 feet high. The absence of fire in the habitat hastens the change from a primarily herbaceous community to a primarily woody plant system which largely eliminates niche space for grassland users. During the sapling stage however when the shrub and hardwood seedling component of the habitat is building and prior to crown closure by the pines, the community is quite complex and will provide for a large population of non-game birds. In short rotation systems, the bird niche diversity and niche space is at the highest point that will occur in the life of the stand in intensive management situations. The duration of this high carrying capacity situation is probably no more than 3 years in slash pine on moist sites where understory development is rapid although it is offset by rapid crown closure. In longleaf stands it may last for 6 to 8 years or more due to the growth habit of longleaf where branching is not heavy and although the saplings are putting on considerable height growth there remains a great deal of growing space for shrubs and hardwoods. The best longleaf sites will support a considerably complex habitat in this stage but on drier areas shrub and hardwood growth will be slow and herbaceous plants will make up a considerable portion of the vegetation.

Closing of the stand is accompanied by a drastic decrease in bird niche diversity and carrying capacity. The plant community approaches the pure monoculture where habitat complexity is minimum. During this stage most of the bird activity will occur along the edges of the stand. Brown Thrashers, thrushes and Towhees will frequent these stands but the non-game bird species diversity will be considerably lower than in the previous stage. The change will usually be more dramatic in slash pine than in longleaf.

From stand closure to age 15 to 20 years the stand remains relatively simple. Slash pine being managed on a short rotation will be dense with little to no understory. Longleaf pine will be somewhat more complex with degree of complexity depending upon frequency of prescribed fire.

At 15 to 20 years the amount of light reaching the forest floor should increase as some expression of dominance creates irregularities in the canopy. Light penetration enhances understory development although the new population of plants may be sparse and unthrifty. At the very best there is some additional complexity to add small but new niches. The newest and expanding niche at this stage however is the availability of tree trunks for bole feeders such as the Downy, Hairy, and Red-cockaded Woodpeckers, and Red-breasted, White-breasted, and Brown-Headed Nuthatches. In addition, Mourning doves will nest in stands in this stage of development.

From 15 to 20 years of age until commercial thinning or the end of rotation in short rotation stands, the complexity of the bird niche diversity and carrying capacity increase slowly. At about age 35 in short rotation management the stand will be harvested and regenerated. In long rotation stands, thinnings and natural mortality will begin to open up the stand enough to allow understory development and increase complexity. As the understory develops, niche diversity and carrying capacity will increase to around 50 to 60 years of age depending upon site conditions and frequency of prescribed fire.

Walker (1962) indicated that final harvest of longleaf may occur at age 70 in long rotation but may go to 120 years. The most significant new feature in old growth stands is the presence of large dead trees resulting largely from lightning strikes and insect attack. These are extremely important habitat features to the non-game bird population. Size of the carrying capacity is dependent on the density of dead trees. There are 17 cavity nesters that use dead trees in the longleaf-slash pine type. These species are most abundant in old growth stands and least abundant in young stands devoid of standing dead trees.

INTERMEDIATE TREATMENTS

Fertilization

Fertilization is a treatment used more in slash pine than in longleaf and primarily in young stands under intensive management. Phosphorus and a combination of phosphorus and nitrogen are the most used elements. They have been applied at two stages, the seedling stage and again at about age 25 to 30. Fertilization has two effects in the seedling stage. First, and most importantly when N is used, the herbaceous plant growth is stimulated. This adds complexity to the habitat but more importantly it probably adds to bird carrying capacity. Second the fertilization effect reduces the amount of time in the seedling stage and shortens the length of time until crown closure. The effect is to reduce the period of time in which a short rotation stand is at its highest carrying capacity for birds but probably raises the carrying capacity during this time.

If fertilization is done again when the stand is 25 to 30 years old, it is carried out in combination with thinning. The most important effect on birds will be on understory development. The interaction of increased nutrients and light should greatly enhance growth of tolerant shrubs and hardwoods and improve the quality of the habitat.

Prescribed Fire

Management of longleaf and slash pine is at least impractical and probably impossible without prescribed fire. In both species the need for control of hazardous fuel build-up, control of understory development, and seedbed preparation exists. As previously pointed out, periodic fire in longleaf pine in the grass stage is necessary for brown-spot needle blight control before leader growth can begin. Burning on about a 3-year schedule during this period suppresses shrub and hardwood development and enhances herbaceous growth. Grassland species benefit but where shrubs are allowed to encroach, niches are added for the shrubland species.

Fire must be kept out of seedling stage slash pine and the small sapling stage of both slash and longleaf. After this period, fire must be used for hazardous fuel and hardwood control. It has three impacts on the bird habitat: (1) control of the understory keeps niche diversity low, (2) reduction of the litter (rough) exposes seeds that would not otherwise be available for forage, and (3) destruction of dead trees which eliminates niches for dead tree feeders and cavity nesters.

There are 3 considerations in prescribing fire that will determine the nature of the impact. First, the season of burning is an important criterion determining impact on the understory as well as direct impact on the

birds. Burning during the spring and summer months may destroy nests of ground nesting birds as well as those of birds nesting in low understory. Spring and summer fires are more effective in killing understory than fall and winter burns. To minimize adverse impact the objective should be to control understory development rather than eradicate it.

Second, frequency of fire is the most important criterion determining structure of the stand understory. Fire is recommended in southern pine management on a 3 to 5 year schedule. Burning more often than every 3 years tends toward eradication of shrubs and hardwoods and greatly lowers bird niche diversity. As previously pointed out, understory control is tolerable in non-game bird habitat but eradication has a serious adverse effect. Where the fuel build-up can be tolerated, burning on a 5-year schedule is preferable to a 3-year schedule.

And third, the type of fire used has bearing on the nature of the effect. Back fires (burning against the wind) move slower, remain at the base of the hardwood stems longer, and are likely to produce more hardwood control than other types. Even though the kill may be greater, the back fire does not blacken, defoliate, and "de-branch" the shrubs and hardwoods and thereby have the immediate dramatic impact of headfires (burning with the wind) or flank fires (burning parallel to the wind). Headfires and flank fires are used primarily for fuel control and can only be used when the crown of the pines are far above the ground. Backfires, however, can be used in young stands.

In the case of the Red-cockaded Woodpecker, much has been made of the need for frequent fires to maintain open stands for foraging by the bird. Based on 24,300 observations on 6 separate clans and taken over the period of one year, we have found that the bird uses longleaf and loblolly stands with well developed understories at least with the relative frequency of stands with no understory. To maintain simple structured stands for the Red-cockaded is, in our opinion, not necessary and is to the detriment of a more species rich non-game bird population.

The numbers of standing dead trees in the forest is affected by the frequency and intensity of fire. These trees are important as a foraging medium for woodpeckers and to provide nest space availability for cavity nesters. Frequent fires will destroy dead pines long before they would fall from natural decay. In addition charring of the bole surface and burning out cavities tends to detract from their usability.

Thinnings

Precommercial thinnings in slash pine have been recommended by Jones (1974) and Langdon and Bennett (1976). It is recommended that precommercial thinning be carried out at least by age 5 and be done whenever stand density exceeds 1000 stems per acre. Numbers of residuals would depend upon product goals. Jones (op. cit.) recommended mechanized thinning by cutting swaths 8 to 10 feet wide and leaving strips 4 to 8 feet wide. Such a disturbance to the stand would of course add to its complexity in vegetation structure and species composition. It will change a stand in which the crowns have closed and carrying capacity dropped to a minimum to habitat favorable to a large variety of non-game bird species.

Commercial thinnings that may be used in slash and longleaf pine are of four general types: (1) low, (2) crown, (3) selection, and (4) mechanical. Smith (1962:92) gave generalized curves describing the distribution of DBH classes that would be removed in each of these procedures (fig. 1). By assuming that crown sizes are roughly correlated with DBH one can get some idea of the relative amounts of understory response.

The low thinning where trees with crowns in suppressed or intermediate classes are removed may change the light regime at the forest floor to some extent but not very much. Understory vegetation may be slightly stimulated but not enough to significantly change niche diversity although carrying capacity may be improved to some extent.

The crown thinning may remove trees in all crown classes but it will concentrate on dominants and codominants. This will have a major impact on the understory. Niche diversity and carrying capacity will be enlarged. Crown thinning will more often be carried out in natural stands than planted stands and is usually the first thinning to be applied.

Selection thinning may be done at any time but concentrates on the removal of dominants. Again, since the larger crowns are being removed, a considerable response can be expected in the understory giving added complexity to the stand.

Mechanical thinning is mostly applied to plantations where rows of trees can be removed without regard to the quality or potential or

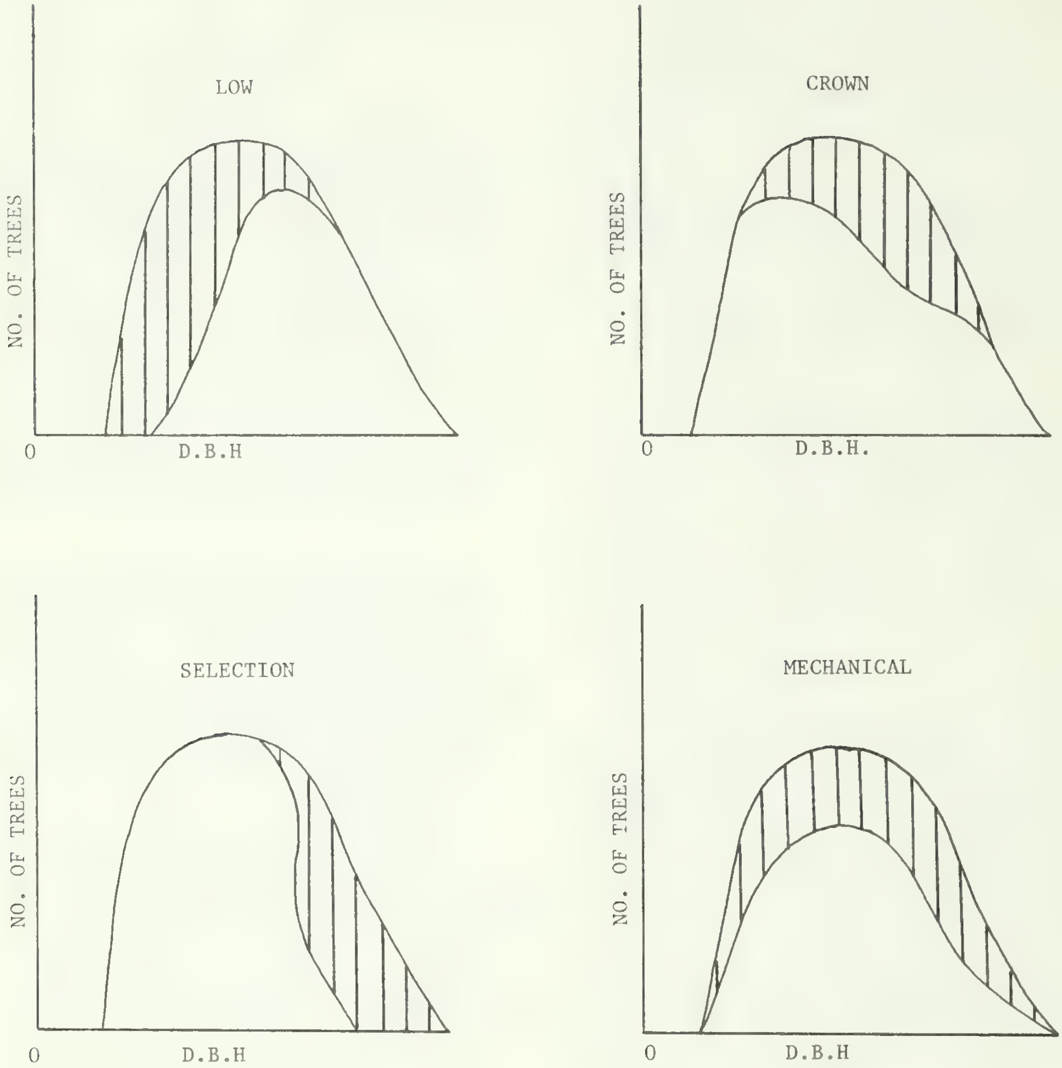

Figure 1.--Distribution of diameter classes that would be removed by 4 methods of thinning (after Smith 1962:92).

residual stems. It is usually a pulpwood cut made at a time in the life of the stand when a light understory is just beginning to develop. The treatment raises the stand from relatively nonproductive conditions in terms of potential to accommodate birds to one which may be very productive.

Sanitation and Salvage Cutting

The last silvicultural treatment to be discussed is sanitation and salvage cutting. These are the least intensive procedures and yet have one of the most important impacts on non-game bird populations. Lightning and insect attack are the primary causes for slash and longleaf pine mortality. Cavity nesting species, of which there are 17 in the longleaf-slash pine type (Table 1), are almost totally dependent on this mortality for nexting opportunities. Where salvage operations remove wounded trees before they decay to a state usable by birds, the cavity nesters are largely missing in the non-game bird population.

Table 1.--Cavity nesting species that use dead trees in the longleaf-slash pine type.

American Kestral	Yellow-bellied Flycatcher
Screech Owl	Carolina Chickadee
Barred Owl	Tufted Titmouse
Yellow-shafted Flicker	White-breasted Nuthatch
Pileated Woodpecker	Red-breasted Nuthatch
Red-bellied Woodpecker	Brown-headed Nuthatch
Hairy Woodpecker	Carolina Wren
Downy Woodpecker	
Eastern Bluebird	
Great-crested Flycatcher	

Dead pine trees may stand for 5 to 15 years and be heavily used for 80 to 90 percent of this time. A dead tree stocking of one stem per acre would be highly desirable. In addition planning for a population of dead trees should be made such that salvage operations do not prevent replacements made necessary by losses to prescribed fire and decay.

SUMMARY

The silvicultural practices in the longleaf-slash pine type that tend to decrease stand complexity by eradicating understory, destroying dead trees, and generally promoting a pine monoculture with a bare forest floor are deleterious to non-game bird populations. This is done by destroying and/or precluding niche development. Long rotation management provides for longer periods of time when the stand may accommodate large bird populations than does short rotation management. Cutting methods for natural regeneration and thinning practices enhance stand complexity and provide for a wide variety of birds. Precommercial thinning creates highly productive habitat in what was previously a simple monoculture. Prescribed burning is a necessary practice in longleaf-slash pine management, but when carried out with the objective of eradicating understory rather than controlling it, the practice has a highly detrimental effect on non-game bird habitat. Furthermore the loss of dead standing trees during prescribed burning can have a dramatic impact on the cavity nesters. Cavity nesters should be managed for by tempering intensity of sanitation and salvage cutting.

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Bird Communities Associated With Succession and Management of Loblolly-Shortleaf Pine Forests

Joseph M. Meyers and A. Sydney Johnson[1]

Abstract.--Published data from 17 winter and 32 summer bird censuses were used to determine changes in bird species composition, richness, and density in relation to plant succession and forest management in loblolly-shortleaf pine forests. Recommendations for habitat management are offered.

INTRODUCTION

Birds are a major faunal component of our forests. They are becoming a more valued recreational resource as man modifies and eliminates forests (Payne and DeGraaf 1973). Birds are useful as indicators of hazardous environmental conditions; the cases of DDT and PCB's provide good examples of how bird populations can forewarn us of potential hazards of pollutants. Bird populations, because of their great mobility, are important seed dispersers and vectors of diseases (Shugart et al. 1975). However, there are few data relating to the ecological roles of birds in forest ecosystems. Research on this subject has been emphasized for less than two decades and has established only a basic understanding of forest avifauna.

Likewise, forest management for birds other than a few game species has received serious consideration only recently. In the past wildlife management was synonymous with game management. "Nongame" management--management of wildlife other than game and commercially important species--is largely a product of increased environmental awareness in the 1970's. But, the term "nongame" is a vague one that does not describe animals; it only tells us what they are not. Wildlife management should not be approached on game and nongame terms but on a holistic basis with consideration for entire plant and animal communities. The purpose of this paper is to describe the possible bird communities that are associated with successional stages of loblolly-shortleaf pine (*Pinus taeda*-*P. echinata*) forests and how they can be managed in ways compatible with sound management of other forest resources.

THE LOBLOLLY-SHORTLEAF PINE PLANT COMMUNITY

The loblolly-shortleaf pine forest type, a major component of the southeastern forest (fig. 1), is widely distributed throughout the Southeast in both the Piedmont and Coastal Plain provinces, except in Florida and Tennessee. The loblolly-shortleaf type includes forests composed of 50 percent or more loblolly pine, shortleaf pine, and other southern pines, except longleaf (*P. palustris*) and slash (*P. elliottii*). Loblolly and shortleaf pines occur separately or in combination and are commonly associated with oak (*Quercus* spp.), hickory (*Carya* spp.), and sweetgum (*Liquidambar styraciflua*) (U. S. Forest Service 1969).

Loblolly-shortleaf forest is a subclimax or developmental stage in a successional sere leading to oak-hickory climax. Oak-hickory and other hardwoods formed the original cover of much of the region (Oosting 1942, Wahlenberg 1949). But, in the Coastal Plain large areas were forested with subclimax pines. Fire, and agriculture practiced by the Indians were important factors in arresting succession. Even in the Piedmont, extensive pine forests occurred on dry upland sites on gray soils derived from granite, gneiss, sandstone, or slate; hardwoods dominated sites on red clay loams (Pinchot and Ashe 1897, Harper 1943, Nelson 1957, Brender 1974).

Land Use History

Beginning late in the 18th Century, a wave of settlement moved southwestward from Virginia and North Carolina, and in little over a half century the entire region was settled by subsistence farmers and planters. Most of the loblolly-shortleaf type is in the old Cotton

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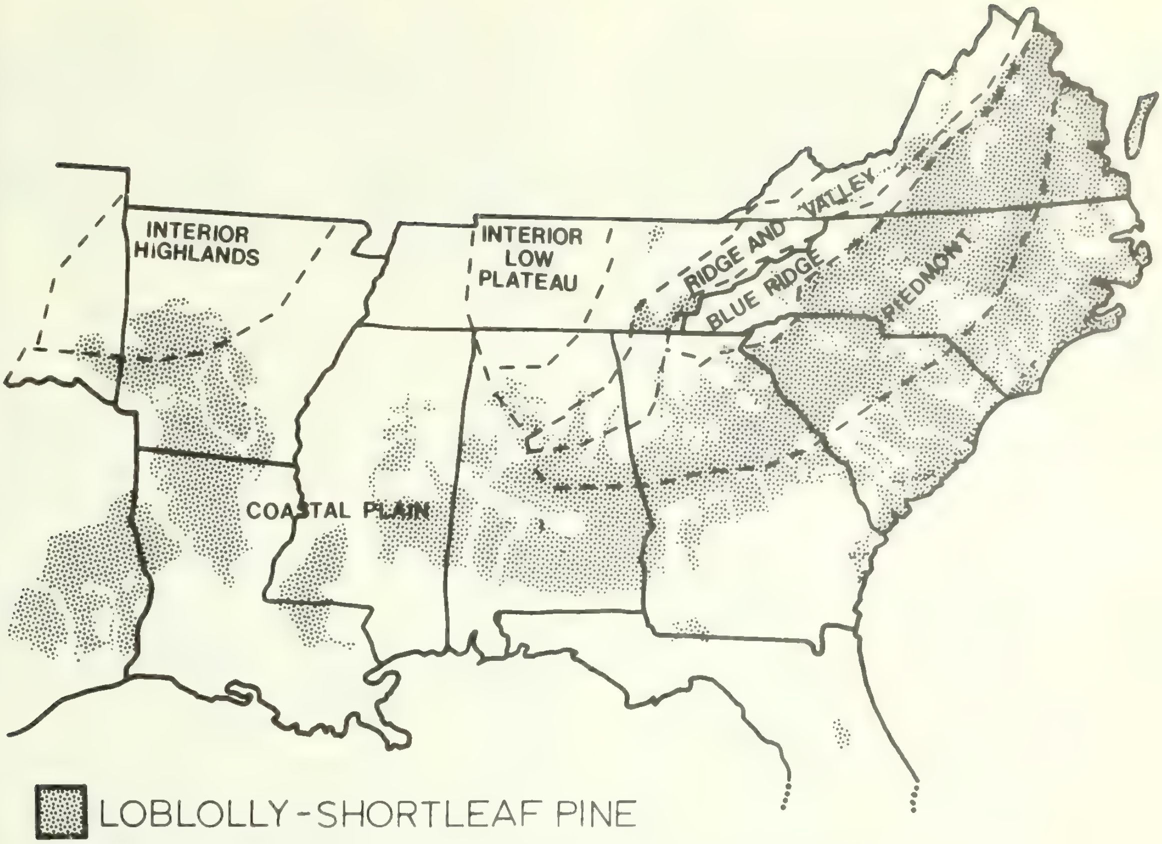

Figure 1.--Loblolly-shortleaf pine forest of the southeastern United States. (U. S. Forest Service 1969).

Belt where intensive agriculture and the nature of the climate, soils and topography combined to produce severe soil erosion and loss of fertility. There were several periods of land abandonment, the most recent and most important coinciding with the economic depression and invasion by the cotton boll weevil (*Anthonomus grandis*) in the 1920's. Abandoned fields were invaded by loblolly pine and, on drier sites, shortleaf pine. Virtually all of the natural stands of loblolly-shortleaf remaining today developed on abandoned agricultural fields. Most stands established before 1945 have been heavily cut. Some have regenerated naturally; others have been planted and are under management for pulpwood.

Secondary Succession

Old Field Stage

On Piedmont uplands the first seral stage is a succession of herbs and grasses through the fifth year. Crabgrass (*Digitaria sanguinalis*) and horseweed (*Erigeron canadense*) dominate the first growing season following cultivation in the Piedmont, and young plant growth, less than 0.3 m, is present during the first bird breeding season. Taller growth up to 2 m develops by the end of the first year. In the second year the dominant species are aster (*Aster pilosus*) and ragweed (*Ambrosia artemisiifolia*). Broomsedge (*Andropogon* spp.) attains dominance in the third year and persists until shaded out by pines, which begin to appear in the third year. Various shrubs (e.g. *Rubus*, *Rhus*, *Prunus*) and small deciduous trees also occur with the pines until canopy closure (Oosting 1942, Johnston and Odum 1956).

Elsewhere in the loblolly-shortleaf type, succession is less uniform and less predictable. This is especially true of the early stages where species composition of invading annuals and perennial grasses may vary with structure and fertility of soils, drainage, and previous land use. Soil fertility may also affect species composition and growth rates of trees.

Pine Forest Stage

By the 11th year pine dominates well seeded areas. Trees are 2.4-4.6 m tall with a broomsedge and shrub groundstory (Oosting 1942). Tree density is dependent on ample seed stocking, but differences in density diminish as stands age; dense pine thickets thin naturally on fertile sites and open-growth stands form closed canopies (Brender 1973).

Canopy closure usually occurs between 10 and 20 years. Only small patches of groundstory plants exist in dense stands of this age class; there is essentially only one stratum of vegetation. More open, natural pine stands have hardwoods of tree size which slowly but steadily increase (Oosting 1942).

A shade tolerant hardwood understory appears in the later seral stages of the pine forest (fig. 2). The decline in pine density is accompanied by a steady increase in density of hardwoods. Natural pine stands 60 to 100 years old have a well developed hardwood understory and ground cover.

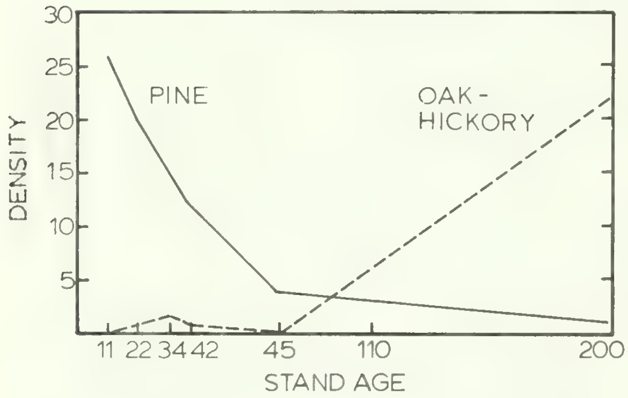

Figure 2.--Piedmont forest succession from loblolly-shortleaf pine to oak-hickory hardwoods. (redrawn from Oosting 1942).

Mixed Pine-Hardwood Stage

During the transition from pine to hardwood forest, habitat conditions are quite diverse. For this discussion we define mixed pine-hardwoods as stands with greater than 10 percent and less than 50 percent loblolly, shortleaf, and other southern pines, except slash and longleaf. Mixed stands usually occur in age classes between 80 and 120 years (fig. 2); however, younger stands can have a substantial amount of hardwoods depending on site conditions. Brender (1973) states that on poor sites, red heart disease (caused by Fomes pini) becomes established earlier, and pine stands begin to break up at age 60. Also, when pines are cut, many stands revert to hardwoods (Wahlenberg 1949); in the absence of fire, root stock of hardwoods in the understory is released when pines are removed.

Mixed pine-hardwoods develop three vertical strata of vegetation--groundstory (0-3 m), understory (3 to 10 m), and overstory (over 10 m). Hortizontal clumping (patchiness) is more prevalent in mixed stands. Lightning, red heart disease, and the southern pine beetle (Dendroctonus frontalis) cause small openings and thereby create uneven age classes. Snags (dead standing trees) become more abundant as the pine forest is replaced by mature oak-hickory forest.

AVIAN COMMUNITIES

We divided the avian community into the two major populations--winter populations and summer breeding populations. More data have been accumulated on breeding bird populations. Data collected in spring and summer are more reliable than those collected during winter or migratory seasons because of breeding season territoriality in most bird species. Large flocks of winter foragers or migrants complicate studies at other times of the year. Statistical differences in non-breeding bird studies are difficult to detect because of high variances or low sampling effort.

For this review we analyzed winter bird populations from 17 census locations throughout the Southeast (table 1). These censuses include from 1 to 10 years of data and range through the succession of loblolly-shortleaf pine to mature oak-hickory forests. We also analyzed summer breeding bird communities from 31 census locations with 1 to 16 years of data (table 2).

Temporal Patterns

In the eastern United States a large proportion of the bird species are migratory. Some species migrate to the Southeast, while other species cross the Gulf of Mexico and spend the winter months in the Neotropics. There also are resident or sedentary species, such as the Carolina Chickadee (Parus carolinensis) [2/] and Tufted Titmouse (P. bicolor). With migration, bird communities change seasonally. During the spring and summer, breeding territories are established and individual breeding birds are relatively sedentary. However, in the winter months interspecific flocks are common in most habitats. For example Kinglets (Regulus spp.), a northern coniferous forest breeder, are abundant winter residents in the southeastern forest and usually are found in pine forests with large groups of chickadees and titmice.

2/ All common names are those standardized and listed with scientific names by the American Ornithologists' Union check-list committee (American Ornithologists' Union 1957, 1973, 1976).

Table 1.--Locations and habitat data for winter bird population censuses of loblolly-shortleaf pine communities.

Census No.	Location	Plot size	Stand type	Percent pine overstory	Stand age[1/]	Years of data	Source[2/]
1	Moulton, Ala.	20 ha	pine	70%	7 yrs. (60%)	1	AFN 24(3)
2	Livingston Par., La.	12	pine	88	6	1	Noble and Hamilton 1976
3	Livingston Par., La.	12	pine	100	20	1	Noble and Hamilton 1976
4	Proffil, Va.	18	pine	100	∿35	7	AFN 2-8(3)
5	El Dorado, Ark.	5	pine	57	∿35	2	AFN 15-16(3)
6	Pine Bluff, Ark.	22	mixed	30	30	1	AFN 10(3)
7	Livingston Par., La.	12	pine	100	45	1	AB 28(3)
8	El Dorado, Ark. [3/]	9	pine	90	mature	5	AFN 7-12(3)
9	Natchitoches Par., La.	9	pine	50	mature	5	AB 25-28(3)
10	El Dorado, Ark.	9	mixed	25	mature (60%)	6	AFN 5-8,10-11(3)
11	North Wilksboro, N.C.[4/]	16	mixed	?	mature	9	AFN 18-19,21,23-24; AB 25-26,29(3),30(6)
12	Savannah, Ga.	10	mixed	30	mature	10	AFN 18-24; AB 25-27(3)
13	Moulton, Ala.[5/]	20	mixed	25	mature	1	AFN 24(3)
14	Raleigh, N.C.	5	oak-hickory	< 5	mature	1	AFN 24(3)
15	Raleigh, N.C.	4	oak-hickory	< 5	mature	1	AFN 24(3)
16	Livingston Par., La.	12	S mixed hdwd.	6	mature	1	Noble and Hamilton 1976
17	McLean, Va.	11	oak-hickory	0	mature	2	AB 25,28(3)

1/ Mature pine stands are >45 years old; mature mixed and oak-hickory stands are >75 years old.

2/ AFN = Audubon Field Notes, AB = American Birds; volume and number are listed with each citation - "Winter Bird Population Studies."

3/ 75% is under forest management, 25% of the area was logged for pine in 1949 (2 years before the date of census).

4/ White pine - shortleaf pine and oak community in the mountains.

5/ Large flocks of Common Grackles and blackbirds were excluded.

Table 2.--Locations and habitat data for breeding bird censuses of loblolly-shortleaf pine forest stands and other pine-hardwood stands.

Census No.	Location	Plot size	Stand type [1]	Percent pine overstory	Stand age [2]	Years of data	Source [3]
1	Livingston Par., La.	12 ha	pine	88%	6 yr.	1	NH 1976 [4]
2	Warner Robbins, Ga.	10	pine	70	~7	1	AFN 6(6)
3	Raleigh, N.C.	13	pine	~50	~7	1	AFN 21(6)
3a	Raleigh, N.C.	13	pine	~50	~9	1	AFN 23(6)
4	Durham, N.C.	7	mixed	35	1-10	1	AFN 20(6)
5	Oakland, Md.	11	pine	100	10-20	1	AFN 3(6)
6	Durham, N.C.	8	pine	95	10-20	1	AFN 20(6)
7	Livingston Par., La.	12	pine	100	20	1	NH 1976 [4]
8	Romney, W.Va.	4	pine	90	20	1	AFN 21(6)
9	Durham, N.C. [5]	10	pine	100	20-30	1	AFN 20(6)
10	Snowhill, Md.	9	pine	97	25-30	1	AFN 2(6)
11	Pine Bluff, Ark.	62	mixed	30	<30	1	AFN 9(6)
12	Athens, Ga.	10	pine	100	~35	1	AFN 1(6)
13	Athens, GA.	8	pine	95	33	1	AFN 17(6)
14	Warner Robbins, Ga.	8	mixed	<20	~35	1	AFN 7(6)
15	Durham, N.C.	10	pine	95	30-40	1	AFN 20(6)
16	El Dorado, Ark.	4	pine	57	35	2	AFN 14-15(6)
17	Southport, N.C.	12	mixed	40	35-40	2	AB 27(6),31(1)
18	Savannah, Ga.	7	pine	95	40-45	3	AFN 19-21(6)
19	Chapel Hill, N.C.	35	pine	92	30-60	1	AFN 20(6)
20	Livingston Par., La.	12	pine	100	45-46	2	NH 1976 [4]; AB 28(6)
21	Durham, N.C.	10	pine	85	70-80	1	AFN 20(6)
22	El Dorado, Ark.	8	mixed	30	mature	1	AFN 11(6)
23	Savannah, Ga. [6]	10	mixed	32	mature	10	AFN 17,19-24(6); AB 25-27(6)
24	Romney, W.Va.	6	mixed	30	mature?	1	AFN 21(6)
25	Fairfield, Ala.	10	mixed	24	mature	2	AFN 3-4(6)
26	El Dorado, Ark. [7]	9	mixed	20	mature	5	AFN 11(6)
27	N. Wilksboro, N.C. [8]	16	mixed	?	mature	16	AFN 8-9,11,14-24(6); AB 25-26,29(6)
28	Chapel Hill, N.C.	9	beech-maple	9	mature	2	AB 27-28(6)
29	Livingston Par., La.	12	S. mixed hdwd.	6	mature	1	NH 1976 [4]
30	Durham, N.C.	11	oak-hickory	<5	mature	1	AFN 20(6)
31	Berkley Spr., W.Va.	6	oak-hickory	0	mature	1	AFN 11(6)
32	Athens, Ga.	9	oak-hickory	~5	mature	1	AFN 1(6)

1/ Pine = loblolly-shortleaf pine; mixed = pine and hardwoods.

2/ Mature pine stands are >45 years old; mature, mixed, oak-hickory, and beech-maple stands are >75 years old.

3/ AFN = Audubon Field Notes, AB = American Birds; volume and number are listed with each citation; see Breeding Bird Census.

4/ Noble and Hamilton 1976.

5/ Edge effect accounted for 4 of 14 species and 220 individuals/km^2.

6/ Slash and longleaf pine are 28% of the overstory, while loblolly is 4%.

7/ Some recent logging was done on the plot.

8/ White pine-shortleaf pine and oak community in the mountains.

Temperature and Latitudinal Gradients

During the winter, the number of bird species (richness) is closely related to the number of frost-free days (Bock and Lepthien 1974, Tramer 1974a). The mild and fairly stable winter climate of the Southeast is apparently important to many bird species that do not tolerate harsh northern winters. Climate does not seem to affect species numbers in areas with more than 245 frost-free days. Because of this relationship, more bird species should be present in pine forests in Louisiana than in Virginia or North Carolina. Also, more species should be present in milder coastal areas than interior habitats. Tramer (1974b) states that temperate zone winter ranges appear to be regulated by the effects of climate on food supply.

In general breeding bird species richness is inversely related to latitude; however, breeding species richness is less in the southeastern than in the northeastern United States. Various explanations for this were presented by Tramer (1974b).

Winter Bird Community

Successional Trends

Quay (1947) completed a detailed study of winter bird populations in an upland plant sere near Raleigh, North Carolina. His study was conducted during one winter, and density estimates within seral stages may reflect favorable or unfavorable climate that year. However, his study does delineate changes in winter bird populations associated with plant communities in that specific region.

Data on winter bird populations from the 17 census locations (table 1) were analyzed for changes in species richness and density with changes in the plant community (figs. 3, 4). In most censuses (source AFN, AB--see table 1) it was not possible to calculate the Shannon Index for species diversity (MacArthur and MacArthur 1961) because data tabulation was in rounded whole numbers (means) and included symbols (+) for uncommon species.

Species richness in winter populations increased in the early seral stage from 7-15 species in old fields to 27-30 species in young open-canopy pine stands with patches of older trees or open wet areas. However, very few data were available for this seral stage, and the apparent trend could be due in part to temperature gradients. Quay's (1947) study showed a slight decrease in species richness from bare ground to herb and broomsedge-pine habitats (fig. 3).

Census data for stands after canopy closure indicate a decrease in species richness, which is not reversed until age 35 (fig. 3). Dickson and Segelquist (1978) found stands of dense pine saplings (age 15) practically devoid of birds; younger and older stands had substantially more species and higher densities. Bird densities (fig. 4) also follow the same trend in the few censuses available for these seral stages. In Louisiana winter bird densities decreased 50 percent (fig. 4, table 1) from a 7-year-old pine stand to a closed canopy stand (age 20); however, a 45-year-old pine stand showed an additional decrease in density from the 20-year-old stand (Noble and Hamilton 1976). These data contradict studies by Quay (1947) and Dickson and Segelquist (1978). Apparently reduced winter bird species and density in the 45-year-old stand was the result of annual burning, which eliminates the lower vegetative stratum (Noble and Hamilton 1976).

From mature pine to mixed pine-hardwood seral stages there is considerably higher density and species richness with the increase in percent hardwoods (figs. 3, 4). Decreases in density and species richness in mature stages of forest succession are apparent in colder, more northerly environments, e.g. North Carolina and Virginia (figs. 3, 4). This difference possibly results from greater availability of food in the southern latitudes (Tramer 1974b).

Species Composition

Fringillids (sparrows, towhees, goldfinches, etc.) are the major group of winter birds in young seral stages. Savannah Sparrow (*Passerculus sandwichensis*), Field Sparrow (*Spizella pusilla*), Dark-eyed Junco (*Junco hyemalis*), and Song Sparrow (*Melospiza melodia*) are common fringillids in old fields during the winter (Quay 1947, Odum and Hight 1957). Other common species in early stage old fields (0-5 years old) are Eastern Meadowlark (*Sturnella magna*), Bobwhite (*Colinus virginianus*), Killdeer (*Charadrius vociferus*), and Mourning Dove (*Zenaida macroura*). As shrubs, vines, and small pines become available for cover and foraging, White-throated Sparrow (*Zonotrichia albicollis*), Cardinal (*Cardinalis cardinalis*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and wrens become abundant.

The pine or mixed pine-hardwood forest is used by a variety of bird groups and foraging guilds. Woodpeckers are common through the winter in forest stands of all ages but are most abundant in mature stands. Golden-crowned and Ruby-crowned Kinglets (*Regulus satrapa* and *R. calendula*) are common to abundant in pine and mixed pine-hardwoods. These species breed in northern coniferous forests and winter in southern pine forests. They are commonly found in flocks with permanent residents, such as Carolina Chickadees, Tufted Titmice, and Downy

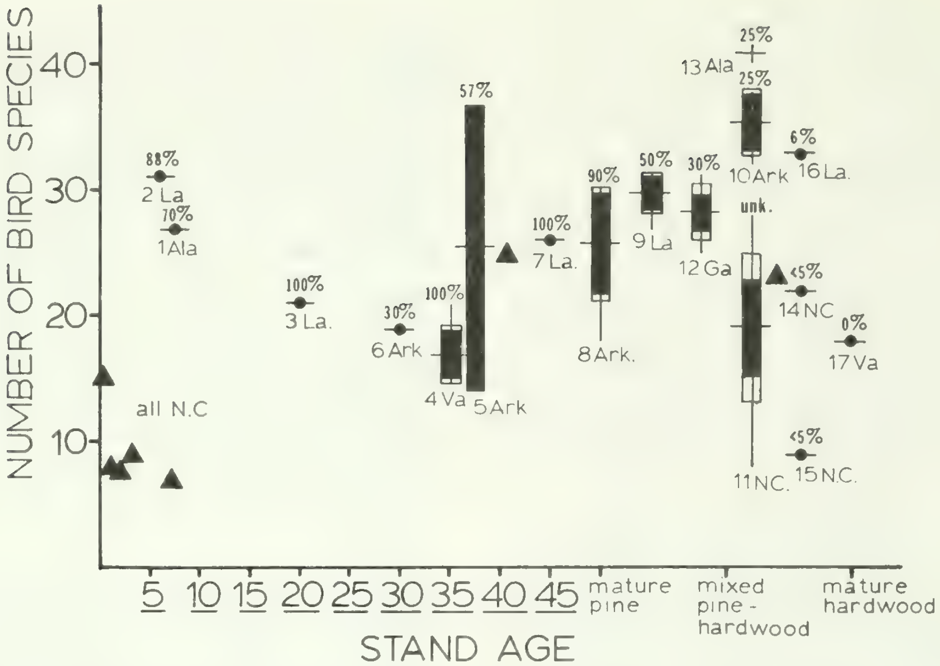

Figure 3.--The relationship of winter bird species richness with succession of loblolly-shortleaf pine forests. Vertical line represents the range, horizontal line the mean, hollow rectangle one standard deviation on either side of mean, and solid rectangle 95% confidence interval on either side of mean. Percent pine is given above each symbol and census location and number below each figure. Solid triangles refer to Quay 1947.

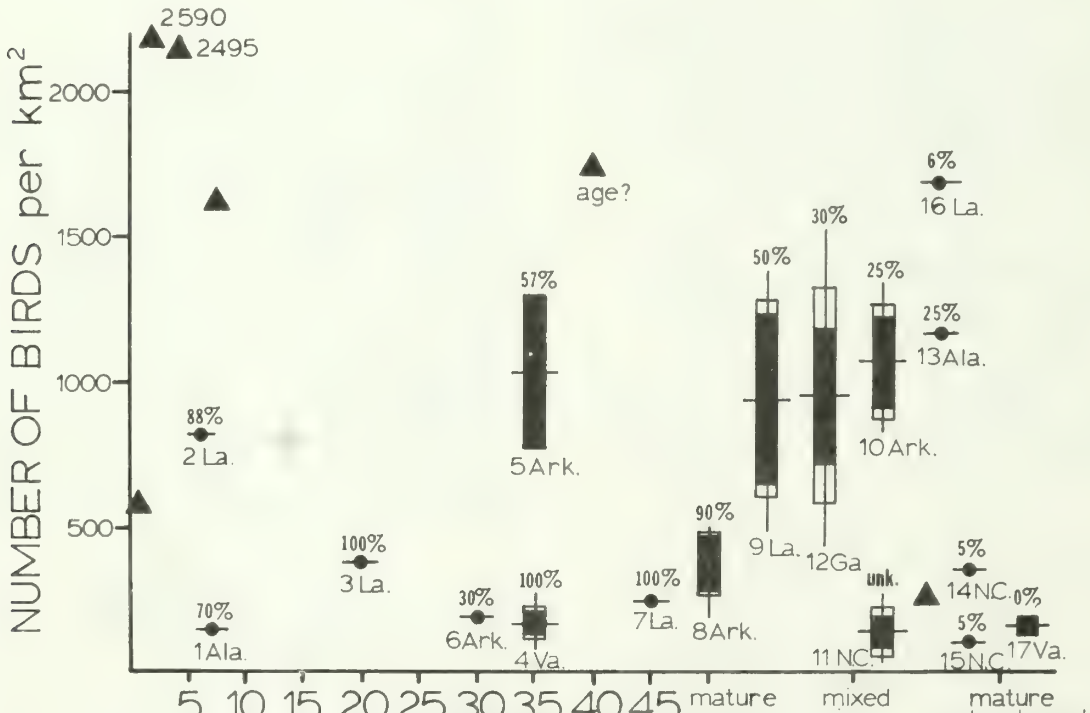

Figure 4.--The relationship of winter bird density with succession of loblolly-shortleaf pine forests. See figure 3 for interpretation of symbols.

Woodpeckers (Picoides pubescens). In most cases pine forests in the Piedmont loblolly-shortleaf type have higher populations in winter than deciduous forests because of the addition of kinglets to the permanent resident populations (Johnston and Odum 1956). Pine warblers (Dendroica pinus), permanent residents, are common in pine stands of all age classes. Another parulid, the Yellow-rumped Warbler (D. coronata), is abundant in some years in young seral stages, and is also commonly found in flocks of permanent residents in older forest stands.

Summer Breeding Bird Community

Successional Trends

Breeding bird habitat in the Southeast is grouped into four broad stages; (1) grasslands, (2) shrubland, (3) pine forest, and (4) hardwood forest (Johnston and Odum 1956). Most of our discussion will be concerned with the first three stages and the transition i.e. mixed pine-hardwoods) from pine to oak-hickory.

Grasslands are predominant in the southern Piedmont and the Coastal Plain during the first 3 years of natural succession. Bird populations and species richness are low during this stage (figs. 5, 6). Only two or three species breed in this habitat in the Southeast. However, in the shrub and young pine stage a rapid increase in breeding density and species takes place. Shrubs add patches and an additional vegetative stratum for nesting. This increase is short-lived as pine canopy closure at 10-20 years eliminates the ground cover and understory vegetation. Densities decrease from 600 territorial males per km^2 to 200-300 per km^2. Breeding bird species also decrease about 50 percent. These reduced populations are common in pine stands from age 15 to 30 years.

Pine tree density decreases rapidly from age 11 to age 34 (fig. 2). This natural thinning allows greater light penetration to the ground and development of understory vegetation. At stand age 35 densities and species of breeding birds again rapidly increase to values similar to those of the shrubland stage. Bird species richness is higher from stand age 40 to 80 than in any younger age class (fig. 5). Again richness and density in the annually burned stand (census 20) was considerably lower (60-70 percent less) than for unburned or irregularly burned plots (figs. 5, 6).

Mixed loblolly-shortleaf pine-hardwood forests are important breeding habitat for many species. Density and species richness in these stands are similar to mature hardwood forests. The average density of breeding pairs (territorial males) in mixed pine-hardwood is 550 per km^2. Approximately 20 breeding species (mapped territories, not visitors) are found in mesic pine-hardwood forest. Bottomland pine-hardwood forests (census 22; figs. 5, 6) are higher in total density and species richness than drier sites. Within the loblolly-shortleaf pine type the mixed pine-hardwoods and mature pine stands have the highest density and species diversity.

Relationships in Breeding Bird Populations

Density and species richness are highly correlated in breeding bird communities. Note that the graphs of species richness (fig. 5) and breeding bird densities (fig. 6) are very similar. Increase in population density is caused primarily by the addition of new species (Tramer 1968). Territoriality would limit increase in density of bird species already present. Species diversity in breeding bird populations also is highly correlated with number of species.

Foliage height diversity, an indirect measurement of the amount of leaf surface area present in the horizontal strata of the forest, is positively correlated with bird species diversity (MacArthur and MacArthur 1961). Roth (1976) shows that spatial heterogeneity or patchiness is also significantly correlated with bird species diversity. Both of these vegetative measurements are useful to bird managers as indicators of bird diversity. But diversity should not be the sole objective in bird habitat management. Densities and species composition and distribution should also be considered.

Species Composition

Figure 7 presents breeding bird species composition and densities with succession in loblolly-shortleaf pine stands. This list is not complete, but it contains the major breeding birds of concern to managers. Rare and endangered species will be discussed in a later section. Birds with large territories, such as raptors, are not well represented in breeding bird censuses because census techniques for breeding raptors are not compatible with passerine census techniques.

Three common breeding species of the grassland stage in the Southeast are Bobwhite, Eastern Meadowlark, and Grasshopper Sparrow (Ammodramus savannarum). Fall and winter Bobwhite populations are highest in 2-year-old fields in pine plantations (Brunswig and Johnson 1972). In unmanaged natural succession Bobwhite breeding populations presumably would be higher in 3- to 5-year-old fields than in managed pine stands of the same age, as management speeds up succession and shortens the duration of optimum breeding habitat. The

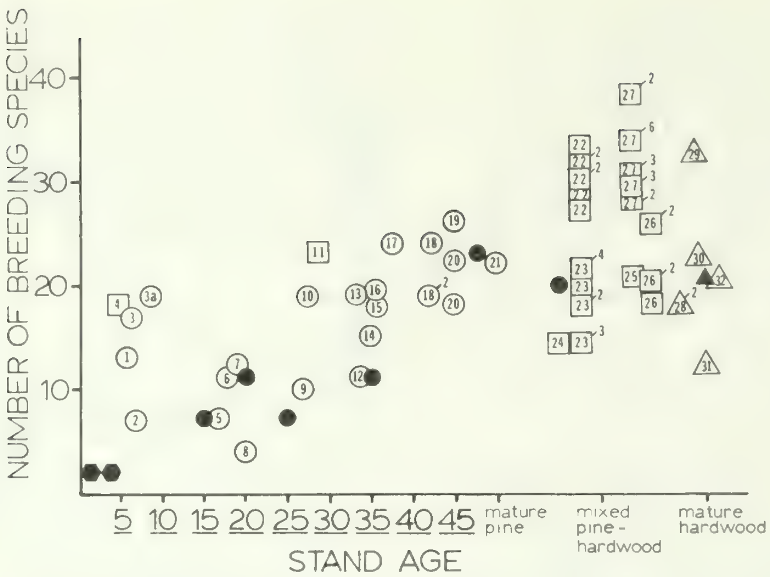

Figure 5.--The relationship of breeding bird species richness with succession of loblolly-shortleaf pine forests. Hexagon = grassland, circles = 50 to 100% pines, squares = 10 to 49% pine, triangles = < 10% pines. Numbers on symbols refer to censuses in table 2. Numbers outside the symbols refer to duplicate points. Solid symbols refer to Johnston and Odum 1956.

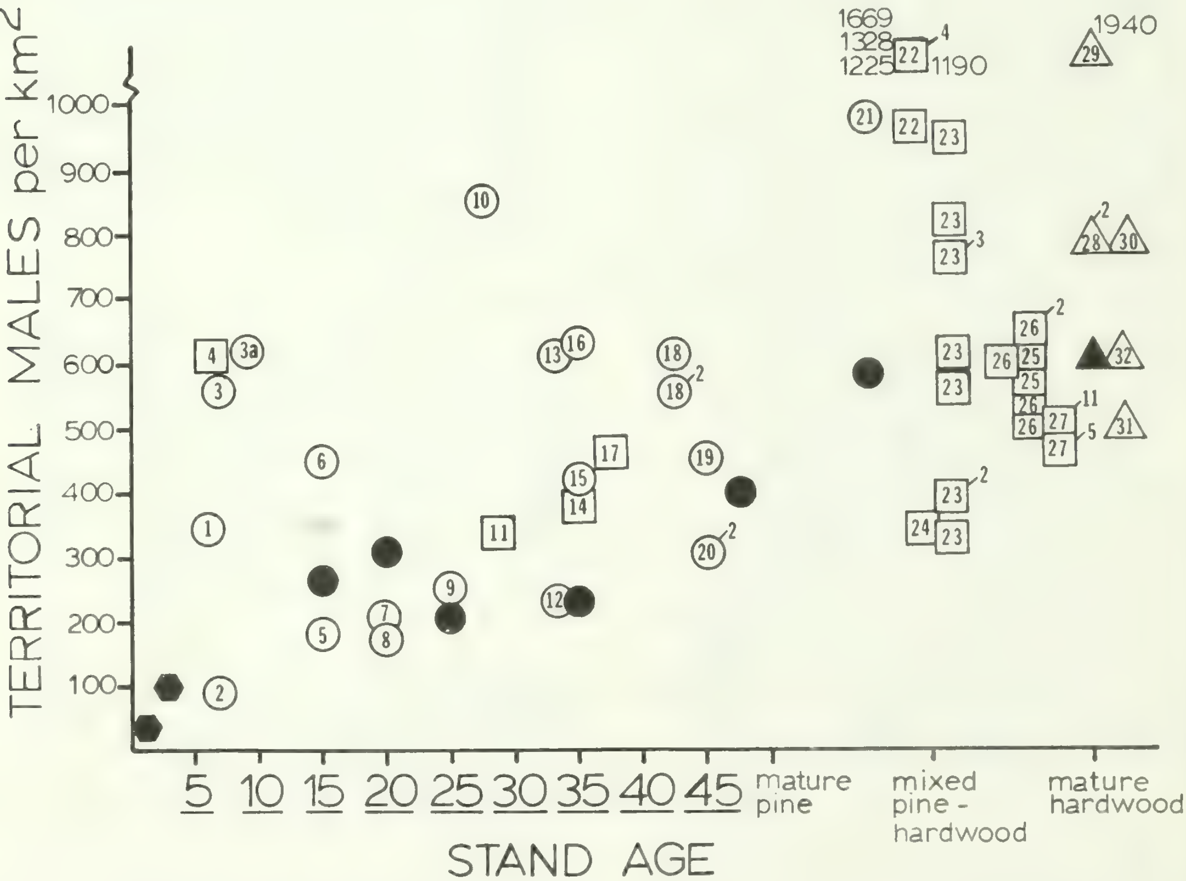

Figure 6.--The relationship of breeding bird density with succession of loblolly-shortleaf pine forests. See figure 5 for interpretation of symbols.

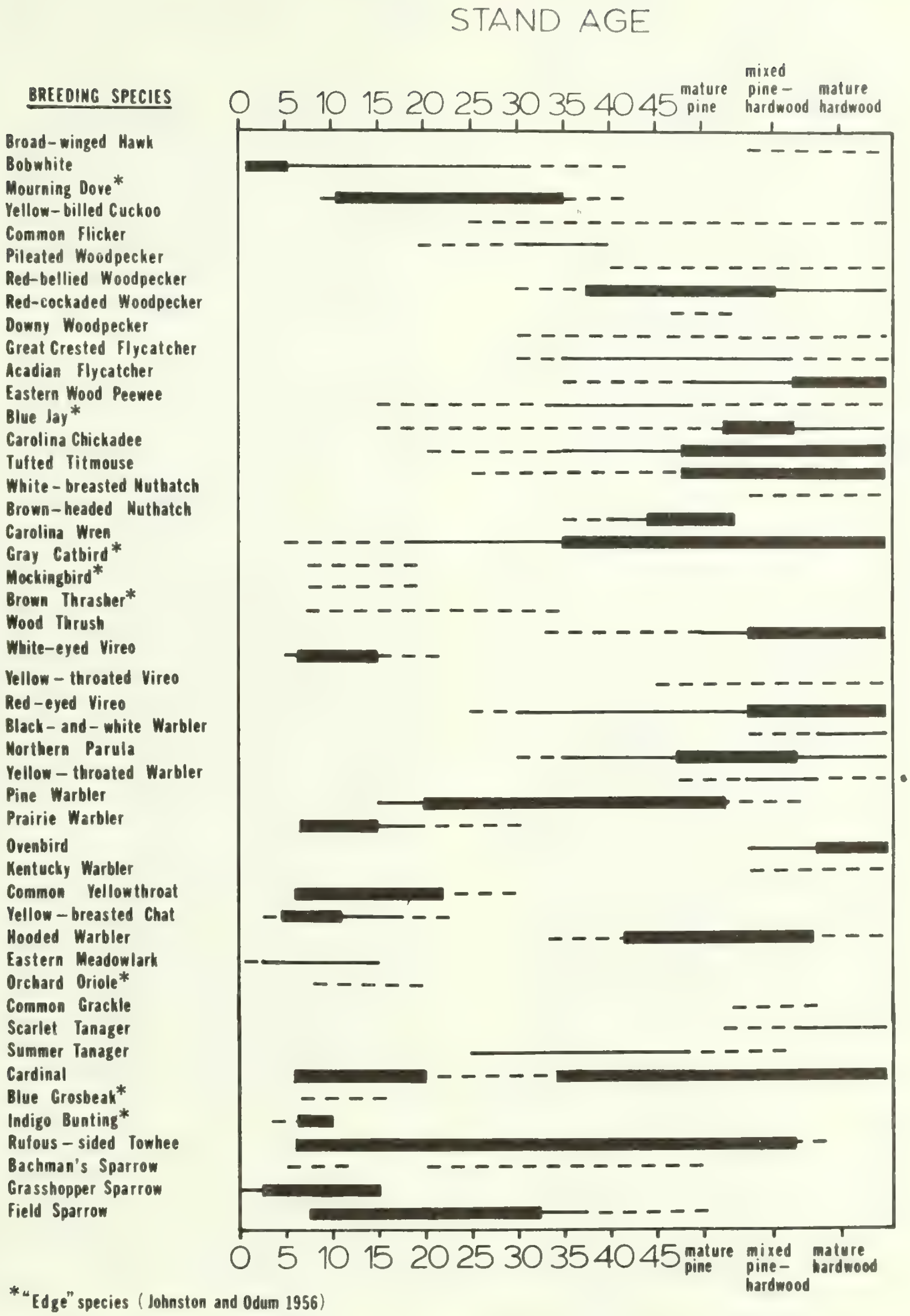

Figure 7.--The approximate density of selected breeding birds in the seral stages of loblolly-shortleaf pine and oak-hickory forests. Dashed line = ≤ 5 pairs per 40 ha, solid line = > 5 < 10 pairs per 40 ha, and solid bar = > 10 pairs per 40 ha. Data from table 2 and Johnston and Odum 1956.

Grasshopper Sparrow and Meadowlark are true grassland species and the only breeding species found in large uniform fields without shrubs or trees (Johnston and Odum 1956). Two other uncommon species not presented in figure 7 are Killdeer and Horned Lark (Eremophila alpestris). Both of these birds feed and nest on essentially bare ground and are pioneer species in the successional series. Horned Larks have been extending their breeding range eastward from the prairies (Johnston and Odum 1956).

The shrubland habitat (age 5-15) is important to "edge species," which require two or more plant communities usually of widely separated ages (Johnston and Odum 1956). These species are common in shrubland and usually also common at forest-shrub boundaries in older stands (fig. 7). A few other species are most abundant only in the shrubland stage and rapidly decrease in forest stands. Prairie Warbler (Dendroica discolor), Yellow-breasted Chat (Icteria virens), Indigo Bunting (Passerina cyanea), White-eyed Vireo (Vireo griseus), Common Yellowthroat (Geothlypis trichas), and Field Sparrow are common breeding species only in shrubland. Mourning Doves, an edge species, become fairly abundant in the latter part of the shrub stage. Edge and shrubland species are a major component of bird communities. Possibly more than 30 to 40 percent of common breeding birds in the Georgia Piedmont belong to this category (Johnston and Odum 1956). These species are also some of the most widely recognized birds found in low density residential areas.

By age 20 most pine stands have closed canopies with shrub and grass cover significantly reduced. However, in natural succession poorly seeded areas and eroded or wet areas often create a patchiness of habitats with clumps of pines interspersed with small openings of earlier seral stages. These openings increase the bird diversity and density in pine stands which otherwise would have low densities.

The Pine Warbler, Brown-headed Nuthatch (Sitta pusilla), and rare Red-cockaded Woodpecker (Picoides borealis) are the only breeding birds restricted to the southern pine forest (Johnston and Odum 1956). Pine Warblers are most abundant in pure stands of pines, and their density decreases significantly with the invasion of hardwood species (fig. 7). The uncommon Brown-headed Nuthatch, a cavity nester, is generally a breeding bird of mature pine stands. The Red-cockaded Woodpecker breeds in mature pine stands with infections of red heart disease and is generally more common in the Coastal Plain than Piedmont.

In southeastern pine forests bird populations are determined mainly by the understory (Johnston and Odum 1956). Grasses under mature pine forests create breeding habitat for Bobwhite and Bachman's Sparrow (Aimophila aestivalis). Thick patches of shrubs or well developed understory in mature pine forests are good breeding habitat for the Carolina Wren (Thryothorus ludovicianus), Great Crested Flycatcher (Myiarchus crinitus), Summer Tanager (Piranga rubra), Yellow-throated Vireo (Vireo flavifrons), Eastern Wood Peewee (Contopus virens), Hooded Warbler (Wilsonia citrina), Northern Parula (Parula americana), Cardinal, Rufous-sided Towhee, and many other less common species (fig. 7 and data from sources in table 2). Many of these species also occur in hardwood forests which usually have a well developed understory.

As pine forests mature, hardwood species replace pines and produce a mixed pine-hardwood stand (fig. 2). These mixed forest types have highly diverse bird populations. Woodpeckers and other cavity nesters, such as the Carolina Chickadee, Tufted Titmouse, Great Crested Flycatcher, and White-breasted Nuthatch (Sitta carolinensis), are fairly abundant at this stage. Some of these species also are found in younger pure pine stands with dead standing trees (Noble and Hamilton 1976). In addition, many predominantly hardwood forest birds, such as the Broad-winged Hawk (Buteo platypterus), Acadian Flycatcher (Empidonax virescens), Wood Thrush (Hylocichla mustelina), Red-eyed Vireo (Vireo olivaceus), Black-and-white Warbler (Mniotilta varia), Ovenbird (Seiurus aurocapillus), and Scarlet Tanager (Piranga olivacea), begin to breed commonly in mixed pine-hardwood stands (fig. 7).

Endangered Species

The only endangered species closely associated with upland loblolly-shortleaf pine is the Red-cockaded Woodpecker. Considerable research is being done on management of this species' habitat (Hooper et al. 1977, Baker 1977, Jackson 1977). The Red-cockaded Woodpecker breeds in open, mature pine stands. The nest trees are almost always infected with red heart disease.

This woodpecker usually occurs in clans of 2-10 birds, with only 1 pair breeding and the remaining birds acting as helpers. Cavities are almost always in mature, living pines and are readily identified by the glaze of white resin surrounding the entrance. The home range of a pair is 14 to 20 ha, and clans of 8 birds utilize up to 65 ha.

Management of this species is achieved by providing suitable nest and roost trees, which include loblolly, shortleaf, longleaf, slash, and pond pines (Pinus serotina) at least 80 years old. Stands for nest sites should have

an average density of 110-124 stems/ha with a basal area of 11 to 14 m^2/ha. Understory should be no more than 4.5 m tall and preferably less than 2 m. The exact stand size necessary for the preservation of the clan is not known, but is in the range of 14-65 ha (Chamberlain 1974).

TIMBER MANAGEMENT IN RELATION TO BIRD HABITAT

Management Trends

Forest management trends have accelerated within the last 20 years. Land ownership, management objectives, and multiple use management are the major areas of change. For instance, forest industrial land holdings in the Georgia Piedmont increased 26 percent from 1961 to 1969, and in 1973 20 percent of the Georgia Piedmont forest was managed by forest industries, mostly for production of pulpwood (Brender 1973). Management of loblolly-shortleaf pine types has become more intense and mechanized. Rotation lengths are shorter with intensive management.

Maintenance of forest stands in earlier successional stages by shorter rotations is eliminating mature pine and hardwood forests. One can readily recognize that compartmental control of a loblolly-shortleaf pine forest with no stands older than 35 years would eliminate many breeding bird species (fig. 7). Short rotation stands lack (1) suitable cavities for nests, (2) an understory nesting stratum, (3) high energy fruits and mast, and (4) deciduous foliage necessary for many songbirds (Johnson et al. 1975). More intensive management, with elimination of hardwoods by herbicides or burning and row planting of pines, further reduces breeding habitat for ephemeral bird species in the grass and shrub stages.

Multiple resource management is now the policy on most publicly owned forests, where a diversity of age classes are maintained. Timber, water, wildlife, and recreation are the major resources of these forests. However, deliberate nongame bird management has not been widely practiced. Much of what happens is incidental to timber and game management.

Only a few studies have been completed on bird populations and the effects of site treatments in the early stages of succession of pine plantations (see tables 1, 2). Obviously shorter rotation lengths in managed pine forests will produce more forest in early stages of succession. More research is needed on bird populations during the first 35 years of managed and unmanaged pine forests.

Succession is predictable only on a macroscopic level (Margalef 1968). Many sites of the same stage of succession will be phytologically different because of past land uses, soil fertility, soil moisture, or microclimate. Local site characteristics are important when overall management decisions are made for songbird habitat.

Harvest and Regeneration

Harvest methods can greatly affect bird communities. Southern pine forests generally are managed in even-aged stands, harvested by clear cutting, seed-tree, or shelterwood cutting. Much of the literature on the effects of even-aged timber management on bird populations concerns clearcutting. Clearcutting with intensive site preparation eliminates the overstory and reduces the site to mineral soil. When soil preparation and planting are done during the fall and winter, the spring vegetation is sparse and all forest breeding birds are eliminated. Killdeers would be the only bird breeding in this habitat (Johnston and Odum 1956, Perkins 1973). However, if the site is not intensively prepared and "whips," shrubs, and logging slash are present, the breeding bird populations are considerably higher, possibly higher than populations in uncut loblolly-shortleaf forest (Perkins 1973). This would be true also for non-breeding bird populations. Snags left in harvested areas are important to cavity-nesting birds such as bluebirds (*Sialia sialis*) (Conner and Adkisson 1974), woodpeckers, and other nesting birds; and they hardly affect timber production goals. Conner and Crawford (1974) found that one-year-old oak clearcuts with slash and debris were excellent foraging areas for Downy Woodpeckers and Hairy Woodpeckers (*Picoides villosus*); however, the source of insect prey was much less abundant in 5- and 12-year-old clearcuts. Perkins' (1973) data on bird species richness of mist blown-injected and bedded (with burned windrows) sites indicated that mist blown-injected sites have more than twice as many species during spring and summer as uncut forests. Many early successional bird species are common in these habitats, as the greater volume of vegetation in the lower strata significantly increases the number of species. Windrows often support plant communities quite different from the adjacent treatment area (Perkins 1973). Shrubs and hardwood saplings in windrows create an "edge effect," which usually increases breeding bird species diversity and density.

Clearcut size and shape, and juxtaposition of different age classes are important in bird management. Arner (1972) reported that the average size of clearcuts in southern forests was 92 ha (range 20-600 ha) on commercial land and 26 ha (Piedmont) to 36 ha (Coastal Plain) on public land. Clearcuts of 20 to 40 ha are

acceptable units for nongame bird management. This range coincides with clearcut sizes suggested for many game species. Clearcuts larger than 40 ha are less important to "edge" bird species, but, if rotations are long (60-80 years), these clearcuts could provide more habitat for forest interior species.

Long narrow clearcuts clearly benefit "edge" species. However, a more important harvest treatment is the undulating boundary (scalloped edge), which is the natural edge of mature systems (Margalef 1968). Meyers (unpublished data) has found significantly higher bird densities on scalloped forest edges of transmission line corridors. It is quite possible that clearcuts with undulating boundaries rather than straight boundaries are higher in bird density and diversity. Undulating boundaries have more edge and also create patchiness of habitat types. Further research on this phenomenon is needed before we make management recommendations. Johnston and Odum (1956) state that boundaries separating habitats of widely different age classes (e.g. grassland and forest) are most important to forest edge bird species. Clearcuts, by maximizing mature forest-grassland edge usually increase densities of edge bird species and bird species diversity. But, we caution against exclusive use of the "edge effect" as a management objective. Many of the edge species are common, whereas forest birds, particularly those of mature pine and hardwoods, are less common, and current forest management trends could further reduce their populations.

Narrow spacing of trees on intensely managed sites usually causes early crown closure, while wider spacing of planted pines results in a delay in crown closure. The delayed crown closure benefits early seral stage birds. Clumping from natural or aircraft seeding and seedling mortality from climatic or edaphic conditions both increase the variety of breeding birds. Regular spacing of trees possibly reduces bird species diversity (Roth 1976).

High breeding bird densities (1800 pairs/km^2) in an intensively managed plantation interplanted with Norway spruce (Picea abies) and European beech (Fagus sylvatica) were reported by Williamson (1970). The plantation was bounded by a fringe of mature beech and oak, field hedgerows, and grassland access roads and firebreaks. The fringe of mature trees was used to screen the new plantation from the public roads. Although southern pine management currently does not include interplanting of hardwoods, birds would most likely benefit greatly by this management.

The other methods of regenerating even-aged stands--shelterwood and seed-tree harvests--do not produce the very low bird diversity and density during the first year after harvest. The presence of overstory trees during the early stages of succession encourages both forest and field or shrubland breeding birds. Also, natural mortality of residual trees associated with these methods (Brender 1973), provides bird habitat for nesting and foraging.

Selection harvesting of loblolly and shortleaf pine is controversial. It is useful for managing small holdings where the landowners expect a regular income at short intervals. Sawtimber and veneer stock are the principal products of uneven-age management (Brender 1973). Since selection harvesting is not a widely used method in the South, there have been no bird studies in uneven-aged loblolly-shortleaf pine. Research on all silvicultural systems as they relate to bird habitat in southern pine forests is scarce.

Intermediate Treatments

At mid-rotation (about 15 years) pine stands, especially on dry sites, are devoid of groundstory vegetation. If there is a pulp market available, stands should be thinned, especially on average to poor sites (Brender 1973). Thinning dense stands can significantly increase timber volume and provide improved bird habitat. Natural thinning encourages a patchier habitat than mechanical thinning and therefore may support more breeding bird species. However, if management of birds is of particular interest, mechanical methods that create non-uniform habitat are suitable, especially on poor to average sites that do not thin naturally.

Burning is commonly prescribed in the management of loblolly-shortleaf pine forests for timber and game. Prescribed burning at 3- to 4-year intervals is useful in hardwood control and can create a patchiness in the understory that may increase bird species and densities. A few species, such as Bachman's Sparrow, benefit from more frequent prescribed burning. However, a vast majority of the breeding birds nest between ground level and 3 m (Preston and Norris 1947); therefore without understory, significant numbers of breeding species are eliminated. Annual burning is not desirable for management of most songbirds, and for timber management generally is unnecessary. Noble and Hamilton (1976) concluded that burning at intervals of 3 to 4 years provided the same results for forest management as annual burning in a 46-year-old stand of loblolly pine. Research is needed on burning rotations greater than 4 years, spot-burning, and other techniques of prescribed burning for non-game bird management.

NATURAL AGENTS MODIFYING BIRD HABITAT

Two animals, the beaver (Castor canadensis) and the southern pine beetle, have a significant impact on forests by creating openings. Reese and Hair (1977) examined birds associated with beaver pond habitat in South Carolina and found highly diverse communities. Dead standing trees, wetland habitat, forest edge, and abundant shrub cover are prominent components of beaver ponds. All of these structures contribute to the increased species diversity in the pond area.

The southern pine beetle is one of the most damaging forest insects in the South (U. S. Forest Service 1969). Damage is within a well-defined area from the Piedmont in central Alabama to south-central Virginia with scattered areas reported on the Coastal Plain. The boundaries of the damage-prone area have changed little since the late 1800's (U. S. Forest Service 1969). Southern pine beetles are natural agents that set back succession. Dead standing trees in damaged areas are valuable woodpecker foraging areas and nest sites for cavity-nesting species. Small, scattered infested areas are important bird habitat; however, large areas are not as valuable to birds.

Lightning strikes, damaging tropical storms, glaze storms, and wild fires are significant agents modifying bird habitat in the loblolly-shortleaf pine type. Before the arrival of European man they were very important to bird species of earlier successional stages. Lightning-struck and wind-damaged trees are readily used by foraging woodpeckers and also are used as nest sites. Large wind-thrown areas create forest openings that are useful demonstration and management areas for the effects of natural habitat modifications on bird populations. Wildfires are of less importance today because of fire control technology. Large burned areas obviously benefit early seral stage birds, but the loss in lives, timber, and property would be great if these fires were not controlled. Man replaces the effects of wildfires by harvesting and other silvicultural practices.

LAND USE TRENDS AND BIRD HABITAT

Regional land use trends can significantly modify bird populations (Dambach and Good 1940, Warbach 1958). In the Southern Piedmont a trend of increased timberland and decreased farmland has been evident for the last 5 decades. Small farms are being displaced by large agribusinesses employing highly mechanized and more intensive practices with fertilization, irrigation, and large open fields without hedgerows. High operation costs have eliminated diverse habitat that is valuable to many wildlife species on farmland. More land is used in crop production on today's highly mechanized farms that depend heavily on outside energy sources (e.g. fertilizer, irrigation, pesticides).

Private lands in relatively small holdings make up a significant percentage of the land area but receive relatively little attention from wildlife biologists. These lands usually are not available for management by wildlife biologists; but, we should make information available to landowners interested in bird management and recommend that they consider management of the entire bird community and not individual species (except in the case of endangered species).

Rapid human population growth in the South is causing large increases in subdivisions and corresponding loss of forest bird habitat. Few studies have been completed on the effects of subdivisions on summer and winter bird communities. None have been done in the loblolly-shortleaf pine type. Commonly subdivisions are thought to provide only House Sparrow (Passer domesticus) and Starling (Sturnus vulgaris) habitat; however, with proper management and initial subdivision planning, these habitats should produce diverse bird communities with very high densities. Subdivisions may be an important factor in the breeding range extensions of many songbird species.

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Forest Bird Communities of the Bottomland Hardwoods

James G. Dickson[1/]

Abstract.--Bottomland hardwoods, which are dwindling in area, support abundant breeding and winter birds. To help birds associated with bottomland hardwoods, land managers should: keep land in forests, maintain diversity of trees species and stand ages, maintain some old stands, maximize stand vertical foliage layers and habitat patchiness, and take special measures for rare bird species.

In 1970 the oak-gum-cypress forest complex, commonly called bottomland hardwoods, extended over about 13 million ha throughout the South (USDA 1975). This forest occurs mainly along major rivers and tributaries that extend into upland pine sites. Bottomland forests have long been recognized for their abundance of game animals, such as deer, turkey, and squirrels (Stransky and Halls 1968), and are also productive of nongame birds.

SITES AND FOREST TYPES

The two major areas in which bottomland hardwoods are found are first bottoms and terraces (Putnam 1951). First bottoms were formed by the present drainage system and are subject to frequent flooding unless afforded levee protection. Terraces were formed by earlier drainage systems and are not flooded except during superflood stages. Within both first bottoms and terraces are ridges, flats, sloughs, and swamps. New land or front is found only in first bottoms.

There are eight primary bottomland hardwood forest types and several variations of these (Putnam 1951). The sweetgum-water oak type is usually found on terrace flats and on first bottom flats and ridges. The white oaks-red oaks-hardwoods type occurs mainly on sandy loam soils of first bottom ridges and on terrace ridges. The hackberry-elm-ash type is found mainly on first bottom low ridges and flats, in first bottom sloughs, on terrace flats, and in terrace sloughs. The overcup oak-bitter pecan type is situated on low, poorly drained flats, sloughs, and in the lowest backwater basins. The cottonwood type is a pioneer type found mainly on front land ridges and well-drained flats. The willow type is also a pioneer type usually found on front land sloughs and low flats. Riverfront hardwoods (sweet pecan, sycamore, hackberry, American elm, green ash) occur on all front lands except deep sloughs and swamps. The cypress-tupelo gum type grows in very low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces, and in river estuaries.

FACTORS AFFECTING STAND COMPOSITION

Natural Succession

Tolerant species gradually replace intolerant species in the successional process. Eastern cottonwood and black willow are the two main pioneer species on recent alluvium. They are intolerant of shade and will not succeed themselves. Cottonwood grows on higher sites having coarse-textured soils and is succeeded by riverfront hardwoods (Johnson 1973), which are usually replaced by the sweetgum-water oak association (Putnam et al. 1960). Black willow establishes itself on fine-textured soils on lower sites and is normally succeeded by the hackberry-elm-ash association (Johnson 1973). As the alluvium ages, these ridges and flats are occupied by a variety of species.

A slow succession of plant communities occurs as sloughs and swamps fill with sediment (Putnam et al. 1960). Normally black willow first occupies the site, then is usually followed by bald cypress and tupelo in swamps and overcup oak and water hickory in small sloughs.

Geological Changes

But differences in forest types mainly result from such geological changes as soil deposition, flooding, and changes in stream courses (Hosner and Minckler 1963, Broadfoot

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and Williston 1973), rather than from natural succession (Odum 1969). Floodwaters deposit coarse sands nearer channels and the fine clays away from channels. These deposits alter the sites and consequently the trees growing thereon. As silt builds up, streams and rivers change directions, thereby altering sites and stand composition.

Animals and Fire

The composition of bottomland hardwood stands has also been affected by insects, diseases, livestock and wildlife predation on seed and seedlings, and fire. For example, cattle can severely compact the soil and eliminate natural regeneration in overgrazed stands. Virtually all species of bottomland hardwoods are vulnerable to fires (Brown and Davis 1973), and past fires have consumed young vegetation in stands and provided entry for decay in older trees (Putnam 1951).

Forest Management Practices

Composition of most stands today reflects past decisions to cut the more valuable species and the more valuable individual trees (Putnam et al. 1960). For example, the tolerant boxelder persists in the understory of riverfront hardwoods and has dominated many sites after more valuable hardwoods were harvested (Johnson 1973).

Management goals, stand composition, and species-site relationships determine the choice of regeneration system. The single tree selection system that has been used and often misued for so long in the South (McKnight and Johnson 1966) has fallen into disfavor. This regeneration system opens stands gradually and favors commercially less desirable, shade-tolerant species (Johnson 1973). Most harvest/regeneration systems now being promoted favor the commercially valuable, intolerant species such as cottonwood, sycamore, and yellow poplar.

Clearcutting is being conducted in even-aged cottonwood and willow stands, and is also appropriate where advanced reproduction is present, where sprouts will provide adequate regeneration, or where an appropriate seed source and receptive site occur together.

Seed tree cuts, where 20 to 25 seed trees per ha are left, can be successful for light seeded species on exposed mineral soil. This technique has been used for cottonwoods (McKnight and Johnson 1966), but is sometimes impractical because good seed crops are difficult to obtain on mineral soil before the site is overcome by brush.

In the shelterwood system, trees are harvested and the stand gradually opened in a series of cuts. Advance reproduction is established before the final cut. The shelterwood system is appropriate for heavy seeded species such as oaks, but is not satisfactory for species with intolerant seedlings (McKnight and Johnson 1966).

Group selection is cutting in small patches (McKnight and Johnson 1966) and is appropriate where advance regeneration, sprouts, or a seed source will fill the vegetative void created by the harvest.

Many mixed hardwood stands are being converted to hardwood monocultures. Cottonwood is the primary species planted, followed by sycamore and sweetgum. Cottonwood thrives on well-drained sandy and silty loams which are common in the batture (area between the river and levee) of the lower Mississippi River (McKnight 1970). About 0.4 million ha are suitable for cottonwood plantations (Dutrow et al. 1970).

Land Use Changes

The conversion of hardwood stands to agricultural crops has had a severe impact on bottomland hardwoods, especially in the Mississippi Delta. In the early 1930's the Delta region of Arkansas, Mississippi, and Louisiana had nearly 4.8 million ha of hardwood forest (Sternitzke 1976). The last Forest Service surveys (1967 for Mississippi, 1969 for Arkansas, and 1974 for Louisiana) showed only 2.9 million ha remained in hardwoods. Most cleared land went into soybean production. From 1964 to 1974, eighty percent of cleared bottomland hardwoods in Louisiana went into soybeans, and most of the remainder was converted to improved pasture and cotton (Sternitzke 1976).

Hardwood land along most rivers throughout the South has also been lost to reservoirs. In East Texas, for example, Toledo Bend and Sam Rayburn reservoirs alone occupy over 100 thousand ha which once supported mostly bottomland hardwoods.

BIRD-HABITAT RELATIONSHIPS

Birds are associated with numerous habitat parameters, such as number of vertical foliage layers (MacArthur and MacArthur 1961), total foliage volume (Willson 1974), foliage density near the ground (Dickson and Segelquist unpubl. data), overstory hardwood/conifer mixture (Hooper et al. 1973), habitat patchiness (Roth 1976), successional stage of stand (Shugart and James 1973), and moisture gradient (Bond 1957, Smith 1977).

Bottomlands are normally moist for at least part of the year, although front ridges with sandy soils and flats with heavy clay soils often have little available moisture. The greater moisture on most bottomland sites

usually allows more understory vegetation and should increase bird density. But long-term flooding and standing water in swamps can reduce or virtually eliminate foliage layers near the ground. This condition reduces ground nesting birds such as the Kentucky Warbler and overwintering ground foragers such as the White-throated Sparrow (Dickson 1974), but may provide some protection from predators for colonial nesters such as herons, egrets, and Red-winged Blackbirds.

Bird Populations in Breeding Season

The moist bottomland hardwoods of the South support an abundance of breeding birds. When bird density and species diversity (calculated from the information theory, Shannon 1948) in a pine, a pine-hardwood, and a mature bottomland hardwood stand were compared in an East Texas study (Anderson 1975), the hardwood stand had a higher bird density (1050 per km^2) during spring, than the other two stands (835 per km^2--pine, 422 per km^2--pine/hardwood). Number of bird species and species diversity were similar in the bottomland hardwood and pine-hardwood stands, but substantially higher than that in the pine stand.

Similar results were evident from a comparison of breeding bird censuses in different habitats in the Louisiana-East Texas area (Table 1). Higher bird densities were recorded in mature bottomland hardwoods than in upland pine and pine-hardwood stands of different ages. Bird density in three bottomland hardwood stands ranged from 752 to 1480 territorial male birds per km^2, about 2 to 4 times that in the best upland stands. Bird species diversity in the bottomland hardwoods was higher than diversities in shorter pine and pine-hardwood stands, but about the same as that in mature upland pine and pine-hardwood stands of similar height. The bottomland hardwood stands would probably have had higher bird diversities but high stand densities (29-45 m^2/ha basal area) limited light penetration, understory vegetation, and habitat patchiness.

Some bird species are associated with stands of particular age and height classes. Bird species associatd with young stands (< 4 m tall) include the Yellow-breasted Chat, Common Yellowthroat, Indigo and Painted Buntings, and Red-headed Woodpeckers that nest in remnant snags.

A sample of species and estimated densities of breeding birds in mature bottomland hardwoods in the Louisiana-East Texas area is shown in Table 2. Although some birds such as the Cardinal and Carolina Wren are ubiquitous in habitat distribution, other species are more restricted to deciduous bottomland hardwood stands. Barred Owls and Red-shouldered Hawks are two birds of prey commonly found in hardwood bottoms, but they are not normally detected in singing male bird censuses of small areas. Wood ducks, which feed on hardwood, mast commonly nest in tree cavities. Many colonial nesters, such as the Yellow-crowned Night Heron, nest and feed in swamps throughout the South. The Yellow-billed Cuckoo is widespread in the canopy of hardwood bottoms. The Acadian Flycatcher is associated with moist forests (Shugart and James 1973, Smith 1977) and is abundant in the Louisiana-East Texas hardwood bottoms. Prothonotary Warblers, Parula Warblers, and American Redstarts are all associated with floodplain forests in the Big Thicket area of East Texas (Bryan et al. 1975), and Prothonotary and Parula Warblers are common during breeding season in swamps (Table 2). The Prothonotary Warbler nests in cavities, which are abundant in trees killed by standing water. The Parula Warbler builds in nest in Spanish moss, which is found in moist habitats (Lowery 1974: 505). The Swainson's Warbler, common in the Louisiana hardwood bottom, is primarily associated with river floodplains and moist woods of the Southern Appalachians (Meanley 1971).

Several rare (or extinct) species have been linked with southern bottomland hardwoods. Hooper and Hamel (1977) determined that nesting habitat of the extremely rare Bachman's Warbler had been bottomlands and headwater swamps that were inundated for short periods and subject to disturbances. The Ivory-billed Woodpecker, a bird of the once extensive mature bottomland hardwoods (Tanner 1942), is now probably extinct because of timber cutting.

Bird Populations in Winter

Mature bottomland hardwoods have dense bird populations during the critical winter period. In a bottomland hardwood stand in East Texas, the estimated winter bird population was 1168 per km^2, higher than numbers in a nearby pine stand (845 per km^2) and in an adjacent pine-hardwood stand (672 per km^2) (Anderson 1975). Number of species and species diversity varied little between stands. In a south central Louisiana mature hardwood bottom, estimated monthly winter populations varied between about 1400 and 2000 birds per km^2, about twice the breeding bird density (Dickson unpubl. data). Winter visitors, which inhabit more northerly habitats or other habitats during breeding season, dominated the bird community. White-throated Sparrow density approached 500 per km^2 and Common Grackles varied between approximately 100 and 1,000 per km^2 (Dickson 1974). Red-headed Woodpeckers, which select habitat with open understories during the breeding season, were common winter residents in the bottomland hardwoods. Yellow-bellied Sapsuckers, Blue Jays, Brown Thrashers, American Robins, Hermit

Table 1.--Comparison of breeding bird density, diversity, and number of species in different habitats in Louisiana and East Texas.[1/]

Stand	Bird species diversity[2/]	Number of species	Bird density (territorial males per km^2)
Pine			
Small sapling	2.32	12	313
Sapling	1.06	3	25
Pole	1.91	9	161
Pole (Cleaveland 1973)	2.21	11	205
Sawtimber	2.66	18	365
Sawtimber (Noble and Hamilton 1974)	2.69	18	300
Pine-hardwood			
Small sapling	2.27	14	359
Sapling	2.24	11	295
Pole	2.11	9	292
Sawtimber	2.63	17	358
Bottomland hardwoods			
Tupelo swamp (Ortego and Noble 1975)	2.69	23	1480
Oak-gum (Dickson 1973)	2.32	16	752
Oak-gum (Hightower et al. 1974)	2.40	22	864

1/Data from U.S. Forest Service studies and Breeding Bird Censuses published in American Birds.

2/Calculated from Shannon information formula (1948), $H' = -\Sigma p_i \ln p_i$, where p_i = the proportion of all birds in a stand of each species.

Thrushes, and Ruby-crowned Kinglets are other birds commonly found in bottomland hardwoods during winter.

Breeding and Winter Bird Populations in Hardwood Plantations

In some hardwood areas, primarily in the Mississippi Delta, uneven-aged stands are being converted to hardwood plantations, mainly cottonwood, sweetgum, and sycamore. These plantations and natural cottonwood and willow stands on new land are deficient in plant species mixture and foliage height diversity, unlike the natural uneven-aged stands of many tree species. Plantations can therefore be expected to have fewer birds and lower species diversity than natural stands. A recent investigation of wildlife populations in cottonwood plantations in Mississippi confirmed these expectations (Wesley et al. 1976). Birds were censused in a natural stand and in an unthinned plantation on Catfish Point and in a natural stand, an unthinned plantation, and a thinned plantation on Huntington Point. During winter there were 79 percent more birds in a natural stand than in an unthinned cottonwood plantation. During breeding season,

Table 2.--Territorial male birds per km^2 in three mature bottomland hardwood stands in Louisiana and East Texas.[1/]

Species	Stand		
	Tupelo swamp (La.)	Oak-gum (La.)	Oak-gum (Tx.)
Wood Duck	20		
Yellow-crowned Night Heron	20		
Purple Gallinule	10		
Yellow-billed Cuckoo	20	86	60
Chimney Swift	40		
Pileated Woodpecker		12	4
Red-bellied Woodpecker	80	12	16
Ruby-throated Hummingbird			16
Downy Woodpecker	80		32
Great Crested Flycatcher	190	6	28
Eastern Kingbird	10		
Acadian Flycatcher	140	62	224
Eastern Wood Pewee			4
Blue Jay	30		
Carolina Chickadee	80		12
Tufted Titmouse	20	80	64
White-breasted Nuthatch			8
Carolina Wren	80	148	64
Wood Thrush		6	
Blue-gray Gnatcatcher			48
Starling	40		
White-eyed Vireo		136	4
Yellow-throated Vireo		31	12
Red-eyed Vireo	10	25	92
Black-and-White Warbler			4
Parula Warbler	110		
Yellow-throated Warbler			12
American Redstart			4
Swainson's Warbler		25	

Table 2.--Continued

Species	Stand		
	Tupelo swamp (La.)	Oak-gum (La.)	Oak-gum (Tx.)
Prothonotary Warbler	200		64
Kentucky Warbler		12	
Hooded Warbler		12	
Red-winged Blackbird	90		
Common Grackle	70		
Summer Tanager	20		12
Northern Oriole	40		
Cardinal	80	93	80
Rufous-sided Towhee		6	

1/ Data from breeding bird censuses published in American Birds: Tupelo swamp (La.) (Ortego and Noble 1974), Oak-gum (La.) (Dickson 1973), Oak-gum (Tx.) (Hightower et al. 1974).

ird density and number of bird species were onsistently lower in unthinned cottonwood lantations than in natural stands. On untington Point in the thinned plantation, the umber of breeding bird species was similar to hat in the natural stand, but bird density as lower. Cavity nesters such as the larger oodpeckers, the Great Crested Flycatcher, nd the Prothonotary Warbler avoided the hinned and unthinned plantations, as did ome birds, such as Hooded and Kentucky Warblers, that are associated with hardwood midtory (Dickson and Noble in press). Although he number of bird species was lower in the lantations than in the natural stands, the nvestigators thought that number of bird pecies in the entire area was probably inreased because some species such as Redinged Blackbirds, Yellowthroats, Yellowreasted Chats, Norther and Orchard Orioles, ufous-sided Towhees, and Warbling Vireos ere commonly found in plantations but not in atural stands.

MANAGING BIRD HABITAT IN THE BOTTOMLAND HARDWOODS

The main threat to birds that inhabit ottomland hardwoods is the conversion of forsts to agricultural land and reservoirs. hus, the first management priority should be o keep bottomlands in hardwoods. Birds such s Prothonotary and Parula Warblers, which ave specific habitat requirements and are associated with bottomland hardwoods will decrease in proportion to their dwindling habitat.

Land managers should maintain a diversity of tree species and age classes. Multiple objectives of bird and timber management can be met through harvesting by single tree selection, group selection, or small clearcuts (e.g., < 40 ha). Interspersion of forest stands with non-forested land such as crops should increase bird diversity.

Some natural mature stands (> 100 years old) should be maintained. Some birds of the bottomlands thrive in the canopy or shaded understory of mature stands. Decayed wood is abundant in natural mature stands but is being eliminated by intensive timber management. Many birds nest and feed in decayed wood. For nest building woodpeckers depend on trees infected with heart rots (Conner et al. 1976). Many other secondary cavity nesters use woodpecker excavations for nests (Balda 1975).

Although diversity of habitat should be used as a general guideline, some large mature stands (> 1000 ha) and corridors of mature trees between stands should be maintained. Such corridors should insure genetic variability by maintaining gene flow between bird populations that might otherwise become isolated.

To increase bird density and diversity, managers should manipulate stands by plantings, thinnings, harvests, etc., that maximize foliage layers beneath the canopy. A basal area of about 20 m^2 per ha over a portion of each stand should allow understory vegetation to develop, but be dense enough to curtail epicormic branching. Basal areas lower than 20 m^2 per ha can be maintained without profuse epicormic branching if thinnings and harvest cuts are conducted gradually.

The same management techniques discussed above plus stand size can be used to enhance habitat patchiness by producing dense clumps of vegetation interspersed with sparse or open areas.

Rare species, colonial nesters, and their respective habitats, deserve special efforts in research and habitat management.

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Wednesday Morning, January 25

EFFECTS OF MANAGEMENT PRACTICES
ON NONGAME BIRDS (continued)

Moderator: J. W. Hardy
Florida State Museum

Oak-Pine and Oak-Hickory Forest Bird Communities and Management Options

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Abstract.--Successional trends, soil-site characteristics, and land use options in the oak-pine and oak-hickory forest types are discussed in relation to bird populations and bird-habitat associations. Management guidelines are provided. Management alternatives include attracting birds to recreational areas, identifying unique birding areas, managing for ecosystem integrity, and enhancing the habitat for cavity nesting bird species.

INTRODUCTION

The 125 million acre oak-hickory and the 34.5 million acre oak-pine forest types make up most of the inland forests of eastern United States and account for 30 percent of all commercial timberland in the United States (USDA Forest Service 1977). In addition, much of the loblolly-shortleaf pine forests would be replaced by oak-hickory species if successional trends were unchecked (USDA Forest Service 1973a).

These vast forests are extremely important to many birds. From 300 to 400 species use the area each year, and 150 to 200 of them nest in the eastern midcontinent region. I recognize that many of these species are not dependent directly on the oak-hickory and oak-pine forest types. Emphasis will be on those bird species that nest or winter in association with oak-hickory and oak-pine types. Migrating species, although important, seem more adaptable to habitat variations and are less affected by most forest management options. Management goals for migrants should be directed to those species with specific needs (Sprunt 1975).

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Many agencies, including the Forest Service, have recently expended much effort to include nongame birds in their management plans. The main cooperative endeavors include: (1) Service-wide Timber-Wildlife Coordination Workshop (USDA Forest Service 1973b), (2) Timber-Wildlife Management Symposium (Slusher and Hinckley 1974), and (3) Symposium on the Management of Forest and Range Habitats for Nongame Birds (Smith 1975). These efforts along with regional workshops will set-the-stage for future management programs and identify high priority research needs.

PLANT COMMUNITIES

The area occupied by oak-hickory and oak-pine forest is highly diverse due to elevation gradients, north-south climatic gradients, topography, soil-site differences, aspect, successional stages, and land-use options. Somewhere between 3,000 and 5,000 plant species occur in the area. Most of the emphasis in this paper will be on vegetative shape or structure and the variations in structural attributes caused by succession, soil-site characteristics, and land use-options.

Natural Succession

Oak-Hickory Forests

Succession is a dynamic process with rapid changes occurring for approximately 40 years before a more or less stable oak-hickory forest community persists. The first year after a cultivated field is abandoned, a wide variety of annual grasses and forbs appear.

Years 3 to 6 show a change from annual species to perennial grasses and forbs, and shrubs begin to invade. Years 6 to 15 are the "brush" years--shrub species dominate and there is an increase in post oak, shagbark hickory, and the clonal tree species. By year 15 many clonal species such as persimmon are decreasing. Between years 15 and 40, an increase occurs in the more climax species such as white and black oak (Drew 1942, Shelford 1963). The quality of the site determines the dominants in the older oak-hickory stands. The best sites will produce white, red, and black oak; the intermediate sites will produce white and post oak; and the poor sites will produce mostly post and blackjack oak.

Oak-Pine Forests

Succession for the oak-pine type is similar to the oak-hickory except that pine seedlings come in after site disturbances. The pine often persist for up to 100 years. In the piedmont area, abandoned cultivated areas will first be vegetated with annual forbs and horseweed and then be invaded with broomsedge. The broomsedge (as a dominant) will be replaced by pine after about 6 years. The oak-pine forests that develop often contain large amounts of yellow-poplar and blackgum after 15 to 40 years of succession. If logging, fire, and other disturbances are eliminated, the oak-hickory forest components will begin to dominate after 40 years (Oosting 1942, Johnston and Odum 1956).

Old field successional stages are different than succession after a clearcut. These differences are more obvious in the oak-pine type than in the oak-hickory type. Old fields proceed into nearly pure pine stands that persist for many years before the oak forest components appear. However, when an oak-pine forest is clearcut, the entire range of oak-pine forest components will be present throughout stand development. For the purposes of this paper, my comments will include forest situations where oak-pine components exist and exclude situations where the land-use option is to maintain and manage for pine.

Soil-Site Characteristics

Soil-site attributes play an important role in the structural development of a forest. The better sites tend to have more plant species and a more developed understory. Soil type and fertility is an ecological force that influences the quantity and quality of food and cover. Thus soil characteristics must be considered as an integral part of a model that associates bird species with attributes of nesting, roosting, and feeding sites.

A relatively tight crown closure is common throughout the oak-hickory and oak-pine forests. Murphy and Crawford (1970) found that 85 percent of their oak-pine plots, and 91 percent of their oak and mixed hardwood plots had a crown closure exceeding 70 percent. Total vegetation production on these plots was generally less than 200 pounds of oven dry material per acre per year. Density of forest stands and crown closure probably influence understory development more than any other factors (Table 1).

Table 1.--Frequency of occurrence of forest understory plants in Missouri (Murphy and Crawford 1970). (In percent)

Plant	Oak-pine	Black-scarlet oak	White oak
Panic grass	26	19	26
Little bluestem and broomsedge	23	13	12
Sedge	14	18	22
Poverty oatgrass	9	8	11
Lespedeza	33	22	24
Tick trefoil	27	27	40
Aster	25	22	24
Pussytoes	17	12	21
Dittany	13	8	15
Goat's rue	13	--	--
Sunflower	9	9	--
Blueberry	42	28	32
Hickory	20	23	16
White oak	19	18	34
Sassafras	18	21	15
Black oak	15	18	15
Post oak	12	11	--
Shortleaf pine	11	--	--
Scarlet oak	10	8	--
Grape	10	12	13
Flowering dogwood	9	10	17
Woodbine	--	9	14
Hawkweed	--	--	8
Blackgum	--	--	10

Stand development after a regeneration cut in upland hardwoods is similar to old field natural succession except for a short herbaceous stage. The first 10 to 15 years after a regeneration cut are referred to as the "brush" stage when 25,000 woody stems per hectare is common. By year 20, 75 percent of these will die on areas with a site index of 55, 80 percent will die on areas with a site index of 65, and 85 percent will die on areas with a site index of 75. By age 80, natural death in unthinned stands will eliminate 90 percent of the woody stems that were present at age 20. By age 80, site index 55 areas will support approximately 600 trees per hectare (average of 23.4 cm d.b.h.), site index 65 will have 460 trees per hectare (average of 27.2 cm d.b.h.), and site index 75 will have 410 trees per hectare (average of 29.2 cm d.b.h.) (Gingrich 1971). These dead and dying trees provide important nesting sites and feeding resources for many birds throughout the rotation age of the forest (Hardin and Evans 1977).

Land Use Impacts

Timber, range, agriculture, and urban activities, along with many other land use options, have a significant impact on the structural characteristics and successional stages of forest areas (Table 2). Species composition changes as vegetation type and structure changes, but all birds are never eliminated. From the diverse habitat preferences of eastern deciduous bird species, and the large number of species selecting edge types, we can assume that these species evolved in an area of high diversity with considerable edge. The greatest potential detrimental impacts of modern silvicultural practices are probably the removal of cull and dead trees and the elimination of large tracts of old growth.

Table 2.--A digitized classification system for the vegetational conditions (structural communities) existing in the area of eastern United States occupied by oak-hickory and oak-pine forest types

- 100 Forest openings
  - 110 Cultivated, row crops
  - 120 Pasture
    - 121 Mowed
    - 122 Grazed
  - 130 Early successional stages or shallow soil
    - 131 Bare ground and rock outcrops
    - 132 Low herbaceous cover, mostly annual plants
    - 133 Herbaceous, mostly perennial grasses and forbs
    - 134 Herbaceous, mostly grasses and forbs with shrub invasion
    - 135 Clonal shrubs such as corralberry, persimmon, and eastern redcedar
    - 136 Small tree glade, with eastern redcedar, winged elm, sumac, persimmon, and mixed hardwoods less than 4 m tall
- 200 Urban areas
- 300 Forest and woodland
  - 310 Regeneration (less than 5 cm d.b.h.)
    - 311 Without site preparation
    - 312 With site preparation
  - 320 Seedling-sapling (5-10 cm d.b.h.)
    - 321 Natural regeneration
    - 322 Artificial regeneration
  - 330 Pole stand (10-25 cm d.b.h.)
    - 331 Natural thinning only
      - 331.1 Limited understory
      - 331.2 Primarily grass-forb understory
      - 331.3 Primarily low shrub understory
      - 331.4 Primarily shade tolerant midstory species in understory
      - 331.5 Well developed multi-layered understory
    - 332 Thinning, selection harvest
      - 332.1 Limited understory
      - 332.2 Primarily grass-forb understory
      - 332.3 Primarily low shrub understory
      - 332.4 Primarily shade tolerant midstory species in understory
      - 332.5 Well developed multi-layered understory
  - 340 Sawlog stand (more than 25 cm d.b.h.)
    - 341 Natural thinning only
      - 341.1 Limited understory
      - 341.2 Primarily grass-forb understory
      - 341.3 Primarily low shrub understory
      - 341.4 Primarily shade tolerant midstory species in understory
      - 341.5 Well developed multi-layered understory
    - 342 Thinning, selection harvest
      - 342.1 Limited understory
      - 342.2 Primarily grass-forb understory
      - 342.3 Primarily low shrub understory
      - 342.4 Primarily shade tolerant midstory species in understory
      - 342.5 Well developed multi-layered understory

350 Old growth (a stand older than "economic rotation age," usually characterized by an overstory of old trees of which many are suitable for cavity nesting species)
- 351 Natural thinning only
  - 351.1 Limited understory
  - 351.2 Primarily grass-forb understory
  - 351.3 Primarily low shrub understory
  - 351.4 Primarily shade tolerant midstory species in understory
  - 351.5 Well developed multi-layered understory
- 352 Thinning, selection harvest
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400 Water influence zones
- 410 Vegetation associated with perennial streams
- 420 Vegetation associated with intermittent streams
- 430 Vegetation associated with large reservoirs
- 440 Vegetation associated with ponds, sinkholes, and springs

Originally, the majority of the eastern United States was a mature (old growth) deciduous forest. The exact pattern of the mosaic of successional stages is unknown. John J. Audubon and Alexander Wilson in their extensive travels throughout the region saw only a limited number of birds that are restricted to brushy successional stages (Griscom and Sprunt 1957). Their journals indicate that extensive tracts of old growth forests were common. Little information is available on bird population levels in climax forest stands. Most stands that have been studied are small fragments (forest islands) and bird population composition and density is strongly influenced by the "edge effect" (Table 3). Most forest interior bird species are able to breed in forest fragments as small as 35 acres (15 ha). However, MacClintock *et al*. (1977) stated that this is apparently only possible if the fragment is "subsidized" by a nearby major forest system.

Table 3.--Population of the common breeding bird species on two mature (possibly climax) forests: (a) oak-hickory forest in West Virginia and (b) oak-hickory hardwoods of the Southern Piedmont Plateau in North Carolina (Loery 1966)

Bird species	Forest habitat A	Forest habitat B
	(Birds/40 ha or 100 acres)	
Red-eyed vireo	47	62
Ovenbird	37	26
Wood thrush	27	51
Cardinal	--	26
Carolina chickadee	--	23
Black-throated green warbler	20	--
Tufted titmouse	--	18
Black and white warbler	17	--
Cerulean warbler	17	--
Blue jay	--	14
Yellow-throated vireo	13	4
Solitary vireo	13	--
Hooded warbler	3	11
Acadian flycatcher	--	11
Brown-headed cowbird	--	11
Scarlet tanger	10	9
Blackburnian warbler	10	--
Eastern wood pewee	7	5
Downy woodpecker	7	--
Great crested flycatcher	7	--
Red-bellied woodpecker	--	7
Carolina wren	--	7
White-eyed vireo	--	7
Rufous-sided towhee	--	5
Common flicker	--	4
Hairy woodpecker	--	4
Summer tanager	--	4
White-breasted nuthatch	3	4
Blue-gray gnatcatcher	3	--
Worm-eating warbler	3	--
Black-throated blue warbler	3	--

BIRD-HABITAT ASSOCIATIONS

The study of habitat selection by birds is a fascinating but complex subject. Each bird seems to have a physiological and behavioral preference for a certain set of habitat attributes. Although there are variations in the habitats chosen by different individuals of the same species, there are generally larger differences between habitats chosen by different species. This fact enables us to describe vegetation conditions (types) that are preferred by certain species. For example, we know that killdeer prefer a bare ground type, that yellow-breasted chats prefer a brushy area, and that pileated woodpeckers prefer extensive areas of mature or over-mature forests. But why should species have a preferred habitat? Because the presence of other species makes it necessary to specialize. This specialization more efficiently utilizes all the components of the environment and lessens competition between species. Any change in vegetation type or structure throughout the oak-hickory or oak-pine forests will change the bird species composition (Tables 4 and 5).

Table 4.--Abundance of bird species found in various stages of oak-pine succession (adapted from Johnston and Odum 1956)

Bird species	Dominant plants and age in years of study area								
	Forbs	Grass	Grass-shrub		Pine forest				Oak-hickory climax
	1-2	2-3	15	20	25	35	60	100	150-200
Grasshopper sparrow	B[1/]	A	A						
Eastern meadowlark	C	B	B	C					
Field sparrow			A	A	A	C	C		
Yellowthroat			B	B					
Yellow-breasted chat			C	B					
Cardinal			C	C	B	B	B	A	A
Rufous-sided towhee			C	C	B	B	B	B	
Bachman's sparrow				C	C	C			
Prairie warbler				C	C				
White-eyed vireo				C		C	C		
Pine warbler					B	A	B	A	
Summer tanager					C	B	B	B	B
Carolina wren						C	C	A	B
Carolina chickadee						C	C	C	C
Blue-gray gnatcatcher						C	B		B
Brown-headed nuthatch							C	C	
Eastern wood pewee							B	C	C
Hummingbird							B	B	B
Tufted titmouse							C	B	B
Yellow-throated vireo							C	C	C
Hooded warbler							C	A	B
Red-eyed vireo							C	B	A
Hairy woodpecker							C	C	C
Downy woodpecker							C	C	C
Great crested flycatcher							C	B	C
Wood thrush							C	C	A
Yellow-billed cuckoo								C	B
Black and white warbler									C
Kentucky warbler									C
Acadian flycatcher									C
Totals: (including rare species not listed above)	15	40	110	136	87	93	158	239	228

1/ A is most abundant, B is abundant, and C is common.

Table 5.--Abundance of bird species found in various age stands after clearcutting a mixed oak stand in Virginia (adapted from Conner and Adkisson 1975)

Species	1-year-old clearcut	3-year-old clearcut	7-year-old clearcut	12-year-old clearcut	Pole stand	Mature stand
Eastern bluebird	A[1/]	C	C	C		
Indigo bunting	A	B	B	C		
Carolina wren	B	C	C		C	
Common flicker	B	C	C	C		
Carolina chickadee	C		C			
Downy woodpecker	C					C
American goldfinch	C	C	C	C		
Brown-headed cowbird	B	C	C	C	B	C
Prairie warbler		B	B	A		
Field sparrow		B	B	C		
Rufous-sided towhee		B	B	B	C	
Yellow-breasted chat		C	C	B		
Hooded warbler		C	C	B		
Golden-winged warbler		C	C	C		
Cardinal		C	C	C		
Blue-winged warbler		C	C			
Brown thrasher		C				
Chestnut-sided warbler		C		C		
Ruby-throated hummingbird		C	C	C		
Hairy woodpecker		C				C
Catbird		C	C			
Worm-eating warbler			C	C		
Kentucky warbler			C			
Whip-poor-will			C			
White-eyed vireo			C			
Eastern wood pewee				C		C
Red-eyed vireo				C		B
Great crested flycatcher				C	C	C
Black and white warbler				C	C	
Scarlet tanager				C	C	C
Ovenbird					A	B
Blue-gray gnatcatcher					B	C
Wood thrush					B	B
Acadian flycatcher					C	C
Tufted titmouse					B	C
Pileated woodpecker						C
White-breasted nuthatch						C
Turkey						C
Ruffed grouse						C
Number of bird species observed	39	162	154	143	44	93

[1/] A is most abundant, B is abundant, and C is common.

The word habitat is often used in reference to a specific mapable unit or obvious vegetation condition. Several species co-exist in any selected vegetation type (mapable habitat unit)--for example, an oak-hickory well stocked pole stand with limited understory (Table 2, number 331.1) might be inhabited by red-eyed vireos, tufted titmice, downy woodpeckers, blue-gray gnatcatchers, and many others. The Volterra-Gause principle asserts the two species cannot co-exist indefinitely if they are limited in their population size by the same factors. This principle implies that co-existing species are limited by different factors. These differences are often complex and subtle. Shugart et al (1975) touched on this principle when they listed groups of birds that co-existed in a given vegetation type, but used the resources differently. For example, kinglets, titmice, and chickadees have similar feeding behavior, but different food preferences; red-eyed vireos, Carolina wrens, and ruby-crowned kinglets eat similar foods, but have different feeding behavior. From a management point-of-view, I feel that it is important to indicate groups of species that will co-exist in one vegetation type without long discussions of the subtle differences (Tables 4 and 5).

One other idea pursued in the management guidelines is the recognition that bird species vary greatly in the specificity of their habitat requirements. The stenoecious species, those with limited adaptability to habitat variability, provide the greatest potential and challenge for management. These species require a specific habitat component (or components) to complete at least one phase of their life cycle. Most of the rare, endangered and threatened species are stenoecious.

Structure of vegetation tends to play a dominant role in bird habitat selection processes (Lack 1933, Miller 1942, Kendeigh 1945, Bond 1957 and others). For example, several warbler species will live in a mature lowland forest with an understory of giant cane but, as shown below they utilize different resource attributes.

Species	Height of nest or foraging area	Feeding sites
Cerulean warbler		Tree tops (canopy)
Yellow-throated warbler	15 m	Glean from small limbs
Black and white warbler		Glean from large limbs
Parula warbler	10 m	Generalist
Redstart		Second growth, large insect prey
Yellow warbler	7 m	Water edge
Prothonotary warbler		Cavity nester
Kentucky warbler	5 m	Feeds by gleaning
Hooded warbler		Feeds by hawking
Wormeating warbler		Steep slope
Swainson's warbler		In giant cane
La. waterthrush	0 m	Along streams

To maintain a full and natural complement of wildlife species, a full and natural complement of plant communities (habitats) must be retained in the landscape. Forest areas are in a continual state of flux and the distribution of comparable areas of vegetation varies with time (succession) and space (aerial extent). Land use, soil, and landform are each horizontal components of habitat heterogeneity whereas the abundance of forb, shrub, midstory, and canopy species are vertical components of habitat heterogeneity. The horizontal and vertical components are interrelated, both between the components and within the attributes of each component. A similar arrangement of components results in a stand. There will be variability within a stand, but generally management resolution will not be concerned with subtle variations. A sufficient number and arrangement of stands of each vegetation condition (seral stage) is necessary to harbor oganisms requiring specific habitats, because succession, land use options, and local disasters will continually cause areas to be unsuitable to some species.

A full vegetative complement including mature and dead standing trees, full understory and shrub layer and wide edges is necessary to maintain diverse breeding bird populations (Linehan et al 1967 and Verner 1975). Siderits (1975) indicated that plant species compositions, age-class and spatial coverage of stands are the most easily manipulated. Maximum diversity is a lower priority objective than maintaining a good distribution of the adapted communities. Communities should be delineated on the basis of plant species dominants, age, and stocking level. This type of management will benefit most species. The remaining species of interest--those with specific habitat components, endangered, threatened, or unique status, or those of economic importance--will require specifically designed programs.

Specialized management plans could be initiated where one or more species requires "featuring" because of low population numbers, restricted range, or special interest. For example, a prescription might call for the control of understory shrub species in a mature forest to create a park-like stand for the Cooper's hawk, barred owl, prothonotary warbler, robin, and red-headed woodpecker. Another prescription would be to maintain an old field in low growing herbaceous cover to provide habitat for eastern meadowlarks, several species of sparrows, and bobwhites. Other birds that show definite habitat preferences include: those that depend on large trees (northern oriole and hooded warbler); those that depend on brushland (common yellowthroat, gray catbird, yellow-breasted chat, white-eyed vireo, and Kentucky warbler); and the forest edge species (mockingbird, yellow warbler, indigo bunting, and blue-winged warbler).

The oak-pine forests are of greater value to wintering bird populations than are the oak-hickory forests (Table 6). At least two major factors enter into this importance--the oak-pine forests are more southern and the coniferous tree component provides additional cover. The true importance of the oak-pine and oak-hickory forests in protecting and feeding wintering populations and, thus, maintaining breeding population is unknown.

Table 6.--Population levels of common wintering birds on three habitat types: (A) oak-hickory forest in Kansas, (B) mixed pine-deciduous forest in Louisiana, and (C) upland oak-hickory forest in Virginia (Ryder and Ryder 1976)

Species	Habitat type		
	A	B	C
	(Birds/40 ha or 100 acres)		
Common grackle	-	132	-
White-throated sparrow	-	82	-
Ruby-crowned kinglet	-	50	+
Red-headed woodpecker	46	-	-
Tufted titmouse	25	14	7
Blue jay	17	23	+
Black-capped chickadee	25	-	-
Carolina chickadee	-	18	15
Pine warbler	-	23	-
Red-bellied woodpecker	8	14	7
Carolina wren	-	18	4
Common crow	-	-	15
Dark-eyed junco	8	14	-
American robin	-	14	-
Yellow-rumped warbler	-	14	-
Cardinal	-	14	-
White-breasted nuthatch	13	-	7
Golden-crowned kinglet	-	9	4
American goldfinch	-	9	-
Downy woodpecker	8	5	4
Brown creeper	+	5	4
Common flicker	-	5	+
Yellow-bellied sapsucker	-	5	+
Red-breasted nuthatch	-	5	-
Bobwhite	-	5	-
Eastern phoebe	-	5	-
Hermit thrush	-	5	-
Hairy woodpecker	+	+	4
Pileated woodpecker	-	-	4

MANAGEMENT GUIDELINES

The wildlife management profession has evolved through four distinct phases since its birth in the United States in the early 1900's. These phases are: (1) awakening of the public, (2) protection of a dwindling resource, (3) single species management, and (4) the presently favored "holistic" approach that involves intensive coordination with other program objectives. This last phase promises to be the most complex, but is potentially the most rewarding.

Setting specific management goals for a resource as large and diverse as eastern United States avifauna is complex, confusing, often contradictory, and maybe somewhat naive. Many approaches have been suggested and/or tried such as to: (1) maximize vertical and/or horizontal vegetational diversity, (2) maximize density of a featured species, (3) maximize number of species in a "key" area--from a recreational point-of-view this maximizes the probability of inter-specific encounter, and (4) manage for economic commodities and let the birds adapt.

In designing management programs, two assumptions should be applied. First, each species should be recognized for its intrinsic value in ensuring the perpetuation of natural ecosystems. Therefore, all native species should be protected and efforts directed toward achieving and/or maintaining self-sustaining population levels. Second, different values can exist compatibly on the same area or in close proximity. Therefore, the needless sacrifice of any value is indefensible and the failure to make the most of all values is a dereliction of sound management. This still allows for areas where trees ought not be cut, others where game ought not be harvested, and others where the public should be excluded.

I won't discuss the many forest management options that exist because these have been discussed in Zeedyk and Evans (1975) and Sander (1977). Three major options exist--even-aged management, uneven-aged management, and preservation.

With few exceptions (Marquis 1967) even-aged management is recommended by hardwood silviculturists, primarily because other systems fail to produce adequate reproduction and growth of desirable intolerant species (Sander and Clark 1971, Trimble 1970, Arend and Scholz 1969, Roach and Gingrich 1968). Three silvicultural cutting systems are employed to achieve even-aged stands--seedtree, shelterwood, and clearcutting. Stands typically pass through six recognizable stages--annual weed, brush, sapling, pole, small sawtimber, and mature sawtimber. The two types of operations in the life of an even-aged stand are the harvest cutting and intermediate treatments (thinnings). The impacts of these operations on bird populations are discussed in detail by Webb et al (1977).

For the purposes of this paper uneven-aged and all-aged management are lumped. Harvesting is done at scheduled intervals and the trees to be cut are selected, whether individually or in small groups. Selection is made on the basis of age, diameter, vigor, form, and species. Noncommercial treatment may follow commercial harvest to remove cull stems and undesirable species. Regulation is by volume and diameter rather than by area. Uneven-aged management tends to favor shade-tolerant species and to maintain a climax state or advance plant succession toward the climax community (Filip 1973). Intolerant or midtolerant species may sprout but fail to develop, thus the selection system is not recommended for oak silviculture. Some woodland owners practice uneven-aged management or "selection forestry" largely for aesthetic reasons.

Uneven-aged management tends to decrease tree species diversity and overstory biomass variations. Thus vertical diversity is enhanced and horizontal diversity reduced. I found no direct information on how these changes influence bird populations but I can speculate on a few changes. The amount of edge habitats would probably decrease within a management unit. Some birds, like the catbird, seem to adjust to small openings (Bond 1957) and may utilize the edges resulting from group selection cutting. Birds that require larger openings would not adjust to uneven-aged management options. The noncommercial removal of snags and cull trees may influence cavity nesting species. Here again information is lacking on specific comparisons of vertical and horizontal plant diversity.

Preservation as a management option has as its objective the development of a natural appearing forest, free from any evidence of logging. Presumedly the end result is the eventual development of old growth or climax plant community. Preservation is the selected objective of many Federal, State, and local agencies as well as private organizations and individuals. Like any other form of management, it has certain impacts upon wildlife habitat. Stand structure and composition will vary with climatic and edaphic conditions, overstory density, past use, fire history, wildlife and livestock browsing, and in the case of bottomland hardwoods, flood frequency, timing, and duration. Bond (1957), Odum (1950),

and others have shown that the diversity of bird species is maximized at the preclimax or middle successional stage and that the number of species as well as total number of individuals is less at the climax stage. A group of forest-dwelling birds such as the red-eyed vireo and the cavity-nesting species of woodpeckers and owls would probably benefit from preservation objectives. Fire, storms, and site differences may create a mosaic of stands within a preservation framework.

I recommend that management adopt the following four-pronged approach, and that research strive to provide the information needed to accomplish this program.

1. Bring the birds to the people by developing habitats in and adjacent to recreational facilities and by enhancing bird viewing opportunities.

2. Bring the people to the birds by identifying unique birding areas, developing access to good birding spots, and educating the people in the art of bird appreciation.

3. Manage for ecosystem integrity by enhancing the structural complexity of physical and vegetational features of the landscape (Table 7), providing a variety of habitat components in a desirable combination to ensure fulfillment of individual species life requirements, and developing a program to identify and protect critical habitats of endangered, threatened, rare, and unique species.

4. Develop and initiate ways to enhance the habitat of the numerous cavity nesting species by accepting the idea that dead and dying trees are part of the natural stand development process. Thinnings should be done by girdling or herbiciding instead of felling. Regeneration goals could often be achieved without removing all dead, dying, and cull trees. Rotation age has a major influence on the cavity nesting bird species. These birds generally require mature forests for at least part of their life cycle. Short rotation cycles create young, vigorous, fast-growing timber stands with few natural cavities and dead trees. At least part of each management unit should be scheduled for a long rotation period--in excess of 100 years throughout the oak-hickory type. The pileated and red-bellied woodpeckers are two examples of birds that require extensive mature forest stands. The barred owls' preferred habitat is an oak woods that is free from understory brush and that has many dead or dying trees--conditions that are often present in over-mature forests.

Table 7.--A summary of the major habitat components considered in the management programs of the Mark Twain National Forest (USDA Forest Service 1973c)

Habitat component	Definition	Quantitative objectives	Qualitative objectives	Remarks
Age-size classes	The proportion of various ages or sizes represented ages 0-90; sizes--sawlogs, poles, saplings, & reproduction	Balance of age-size by compartment, 34% sawlogs 44% poles, 11% saplings, and 11% regeneration size	A balance of age-size classes by vegetation types when adequate acreage present	Primarily commercial forest land, managed under an even-age system
Mast	Nuts and seeds from hardwood trees	40% of the compartment acreage in mast-producing stands (30% for pine compartments)	Hardwood vegetation types and species characteristics of the compartment	All hardwoods and hardwood-conifer types of commercial forest land and unproductive land
Old growth	Mature and overmature stands of all types	10% of the compartment acreage in old growth conditions	Vegetation types and sites representative of the compartment	All forested types and all land classes suitable for growing trees
Temporary forage	Tree reproduction less than 10 yrs. old	11% of the commercial land managed under even-age system (12% for pine)	Interspersion of regeneration areas among existing vegetation types and sites	All regeneration cuts and type conversion areas 0-9 years of age
Permanent forage	Areas managed for forbs, grasses, shrubs, or small trees	More than 9% of the compartment acreage (more than 8% for pine compartments)	A variety of permanent forage conditions and areas within compartments	Forest openings, grass lands (pasture and hay meadows), glades, upland drainages, rights-of-way, and savannas

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Cove Forests: Bird Communities and Management Options

Robert G. Hooper[1/]

Abstract.--Over 60 species of birds regularly nest in cove forests. A primary goal for managing nongame birds is to provide suitable habitat, at some stage of the rotation, for each species that naturally occurs in a forest type. Even-aged stands up to 25 acres and rotations of 100 years should meet that goal in cove forests. Commercial thinnings benefit shrub nesting species but remove potential sites for cavity nesters.

INTRODUCTION

The forests of mountain coves, ravines, and adjacent moist slopes of the Southern Appalachians are among the most productive hardwood types of the North Temperate Zone. They have great esthetic value, protect water quality, and are of considerable botanical interest. Depending upon stand age and species composition, these forests provide habitat for many species of birds. In this paper I review existing information on breeding communities of birds in cove forests and predict possible effects of forest management options on these communities. Cove forests also may be important to winter bird populations, but data are lacking for an interpretation.

THE COVE FOREST

Cove forests are found at elevations between 1,000 and 4,500 feet in the Southern Appalachians of Virginia, Tennessee, North Carolina, South Carolina, and Georgia. They occupy coves, ravines, and adjacent moist lower slopes. An estimated 3.5 million acres of cove forest exist in the Southern Appalachians (D. E. Beck, pers. commun.). Some 30 tree species occur in cove forests; 6 to 8 may be prominent in any particular stand (Braun 1967, p. 199-205; Davis 1930; Whittaker 1956). At least 10 of these species are considered of high commercial value (table 1).

Various forest cover types have been recognized in coves (table 2). These types grade into oak, oak-hickory, and oak-pine types on relatively dry sites. At high elevations, cove forests give way to northern hardwoods and spruce-fir. Hemlock commonly dominates on floors of ravines at all elevations and on broad valley flats around 4,000 feet above sea level.

Understory conditions vary tremendously: both open parklike and extremely dense understories occur. Rosebay rhododendron (*Rhododendron maximum)* generally forms dense understories near streams and beneath hemlock-dominated stands. In stands which are predominately hardwood, a large variety of shrubs and small trees occur in the understory. Many stands with an open understory have a lush herbaceous layer (Cain 1943).

While stands at or near climax contain primarily tolerant species--sugar maple, buckeye, hemlock, and beech (table 1)--even the intolerant but long-lived and fast-growing yellow-poplar occurs sparingly (Fowells 1965, p. 261). Climax stands are normally dominated by several species.

BIRD COMMUNITIES

General

All of the 62 species of birds known to nest in the different seral stages of cove forests (table 3) can be found nesting in other forest types in the Southern Appalachians or in other physiographic regions. Some stands have an unusually large number of species (table 4), but the average cove forest does not have more species than other types in the Southern Appalachians (Fawver 1950).

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Table 1.--Major tree species of cove forests

Species	Potential commercial value	Tolerance to competition
Yellow-poplar *(Liriodendron tulipifera)*	High	Intolerant
Basswood *(Tilia spp.)*	High	Tolerant
Black cherry *(Prunus serotina)*	High	Intolerant
Black walnut *(Juglans nigra)*	High	Intolerant
White ash *(Fraxinus americana)*	High	Intolerant
White oak *(Quercus alba)*	High	Intermediate
Northern red oak *(Q. rubra)*	High	Intermediate
Cucumber tree *(Magnolia acuminata)*	High	Intermediate
Sugar maple *(Acer saccarum)*	High	Very tolerant
White pine *(Pinus strobus)*	High	Intermediate
Sweet birch *Betula lenta)*	Medium	Intolerant
Black locust *(Robina pseudoacacia)*	Medium	Intolerant
Chestnut oak *(Q. prinus)*	Medium	Intermediate
Hickories *(Carya spp.)*	Medium	Intolerant
Yellow buckeye *(Aesculus octandra)*	Medium-low	Tolerant
Beech *(Fagus grandifolia)*	Low	Very tolerant
Red maple *(A. rubrum)*	Low	Intermediate
Yellow birch *(B. lutea)*	Low	Intermediate
Fraser magnolia *(Magnolia Fraseri)*	Low	Intermediate
Silver bell *(Halesia monticola)*	Low	Tolerant
Hemlock *(Tsuga canadensis)*	Low	Tolerant
Blackgum *(Nyssa sylvatica)*	Low	Intolerant

Table 2.--Forest cover types of coves, ravines, and adjacent moist slopes in the Southern Appalachians

SAF type1/	R-8 Wildlife habitat management handbook type2/	R-8 Timber manage. types3/
Yellow-poplar-white oak-northern red oak	Yellow poplar-white oak-northern red oak	Yellow poplar-white oak-northern red oak
Yellow-poplar-hemlock	White pine-yellow poplar-hemlock	White pine-yellow poplar
Yellow-poplar		Hemlock-hardwood
Hemlock		Yellow-poplar
White pine-hemlock		Hemlock
Northern red oak-basswood-white ash		

1/ Anon. 1967. Forest cover types of North America. Soc. Amer. For., Washington, D. C.

2/ Anon. 1971. Wildlife habitat management handbook. U. S. Dep. Agric., For. Serv., Region 8, Atlanta, Ga.

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Table 3.--Relative value of seral stages of cove forest as nesting habitat[1/]

Species	Virgin		Second-Growth		
	Hardwoods	Hemlock	Sawtimber	Pole	Sapling
Broad-winged Hawk	X	X	X		
Ruffed Grouse	X	X	X	X	XX
Yellow-billed Cuckoo			X	X	
Screech Owl	X		X		
Barred Owl		X	X		
Ruby-throated Hummingbird					X
Common Flicker	X	X	X	X	
Pileated Woodpecker	XX		XX		
Hairy Woodpecker	X	X	X		
Downy Woodpecker	X		X		
Great Crested Flycatcher		X	X		
Eastern Phoebe			X		
Acadian Flycatcher	X	X	XX		
Eastern Wood Pewee		X	X	X	X
Blue Jay	X	X	X	X	
Black-capped Chickadee	X	X	X		
Carolina Chickadee		X	XX	X	X
Tufted Titmouse	X	X	XX	X	
White-breasted Nuthatch		X	X	X	
Red-breasted Nuthatch		X	X	X	
Brown-creeper		X	X		
Winter Wren	X	X	X	X	
Carolina Wren	X		X	X	
Gray Catbird		X	X	X	XX
Brown Thrasher				X	X
American Robin		X	X	X	X
Woodthrush	XX	XX	XX	XX	
Veery	X	X	X	X	X
Blue-gray Gnatchatcher			X		X
Golden-crowned Kinglet			X		
Cedar Waxwing				X	
White-eyed Vireo					X
Yellow-throated Vireo			X	X	
Solitary Vireo	XX	XX	XX	XX	X
Red-eyed Vireo	XX	X	XX	X	X
Black-and-white Warbler	X	X	XX	X	X
Swainson's Warbler			XX	X	
Worm-eating Warbler	X		X		
Golden-winged Warbler				X	X
Northern Parula	X	X	X	X	X
Black-throated Blue Warbler	XXX	XX	XX	XX	
Black-throated Green Warbler	XX	XXX	XX		
Blackburnian Warbler	X	XXX	X	X	
Yellow-throated Warbler			X		
Chestnut-sided Warbler				X	XX
Pine Warbler			X		
Prairie Warbler					X
Ovenbird	X	X	XX	X	
Louisiana Waterthrush			X		
Common Yellowthroat					X
Yellow-breasted Chat				X	XX
Hooded Warbler	X	X	XX	X	X
Canada Warbler	XX	XX	X	X	X
Scarlet Tanager	X	X	X	X	X
Cardinal	X		X	X	X
Rose-breasted Grosbeak		X	X	X	X
Indigo Bunting				X	X

Table 3.--Continued

Species	Virgin Hardwoods	Virgin Hemlock	Second-Growth Sawtimber	Second-Growth Pole	Second-Growth Sapling
American Goldfinch				X	X
Rufous-sided Towhee			X	X	XX
Dark-eyed Junco	XX	XX	XX		
Chipping Sparrow				X	X
Field Sparrow				X	X
Song Sparrow				X	XXX

1/ X = Species occurs at low frequencies and densities. Also occurs in other habitats at greater densities.
XX = Species occurs at medium densities but also occurs at equal or greater densities in other habitats.
XXX = Species occurs at highest densities within the region.

The table is based on literature cited in the text and personal observation by the author.

Table 4.--Densities and numbers of species of birds in cove forests1/

Stand condition	Bird density (pairs/100acres)	Number of species	Number of censuses
Seedling and sapling	66-321	8-13	3
Poletimber	270-296	21-35	2
Sawtimber	333-510	17-30	2
Virgin Hemlock	230-430	13-23	4
Hardwoods	183-370	9-19	4

1/ Values in table taken from literature cited in text.

A 1-year-old clearcut had 66 pairs of breeding birds per 100 acres (Lewis and Smith 1975). The mean for all other cove forests reported (Fawver 1950; Holt 1974; Mellinger 1969-1975, 1977; Odum 1950) was 314 pairs per 100 acres, and the highest was 510 pairs per 100 acres. These densities are greater than for other forest types in the Smoky Mountains (Fawver 1950) and for most other forest types in the South and Southeast.

Virgin Stands

Fawver (1950) censused four virgin cove forests that were dominated by hardwoods and two that were dominated by hemlock. Odum (1950) and Holt (1974) censused a virgin hemlock stand at a 12-year interval. Density of pairs of breeding birds per 100 acres ranged from 183 to 370 in the hardwood stands and from 230 to 430 in the hemlock stands (table 4). The virgin hardwood areas had 13 to 23 species of breeding birds and the virgin hemlock had 9 to 19 species. A total of 28 species nested in the virgin stands. Each of these species nests in other habitats, both in the region and in other regions.

Species most dependent on virgin stands appear to be the Black-throated Blue Warbler, Black-throated Green Warbler and Blackburnian Warbler. Although these species occur in seral stages of the cove forests and in other forest types, they reach high densities in the virgin cove forests. The Black-throated Blue Warbler was the most abundant species in the hardwood-dominated cove forests, accounting for up to 59 percent of the density of

breeding individuals: one area had 185 breeding pairs per 100 acres (Fawver 1950). Although densities of the Black-throated Blue Warbler were less in hemlock-dominated forests, it was still an abundant species. The Blackburnian Warbler and the Black-throated Green Warbler were associated mostly with hemlock stands.

Twelve cavity nesters used the virgin stands but were usually more abundant in the second-growth stands.

Second-Growth Stands

Mellinger (1969-75, 1977, pers. commun.) censused a mature sawtimber stand for 9 consecutive years. Odum (1950) and Holt (1974) censused a poletimber stand in 1946-47 and in 1959-60; they revisited the stand in 1971-72 when it was in a sawtimber stage. They also censused a stand in the sapling stage in 1946-47 and 1959-60, and again in 1971-72 when in a pole stage. Lewis and Smith (1975) censused a stand 1 growing season after clearcutting.

Population density and number of species in the second-growth pole and sawtimber stands were similar to those of the virgin stands (table 4). Bird species found in the virgin stands were well represented in the second-growth sawtimber stands (table 3). The second-growth stands did not have the high densities of Black-throated Blue Warblers that Fawver (1950) reported for the virgin stands. Holt (1974) found 44 pairs of Black-throated Blue Warblers per 100 acres--the highest reported in second-growth stands.

The pole stands had surprisingly large bird populations (table 4). This abundance may have been due to a light stocking of trees, the occurrence of hemlock, and a well-developed rhododendron understory (Odum 1950; Holt 1974). Pole stands of yellow-poplar and other hardwoods would probably have much lower densities.

The composition of bird species was considerably different in sapling plots than in older stands (table 3). For example, Odum (1950) reported a percentage difference (which takes into account the abundance of each species) of 97.9 between a sapling and a virgin stand.

TIMBER MANAGEMENT PRACTICES

Cove sites are highly productive and are typically classed as good to excellent for timber growth. Oaks grow 65 to 90 feet and yellow-poplar grows 90 to 140 feet in 50 years (Trimble 1973; Beck and Della-Bianca 1972). At 80 years, well-stocked stands of second-growth hardwoods contain about 37,000 board feet per acre on the best sites and 25,000 board feet per acre on lower quality sites (Frothingham 1931).

Since the majority of desirable timber species are relatively intolerant of competition (table 1), cove forests are generally managed for timber under even-aged silvicultural systems (Trimble 1973).

The individual selection silvicultural system, leading to all-aged stands, may be used where disturbance to the canopy must be minimized to protect esthetic values or stream banks. Because selective cutting favors tolerant species like buckeye, hemlock, beech, and sugar maple, it may reduce stand diversity. Of the tolerant species, only sugar maple and basswood have high commercial potential. Selection cuts heavy enough to encourage regeneration of intolerant species may result in understocked stands and high-grading (Trimble 1973).

Group selection cuts as small as 0.25 acre can regenerate the intolerant species, but openings of 0.5 to 1.0 acre are more desirable for growth of the regeneration (Trimble 1973). However, the impact of deer browsing upon the reproduction can be severe in openings that small (Harlow and Downing 1969).

Shelterwood cuttings are silviculturally feasible and could be used to maintain a forested canopy. The shelterwood system may be especially suited to securing advanced regeneration of heavy-seeded species such as oaks. The seed tree method is unnecessary in cove forests because many of the hardwoods sprout readily, advanced regeneration is normally present, and the light seeds of certain species carry long distances (Trimble 1973).

Clearcutting offers the greatest potential for intensive timber management. Maximum reproduction and growth of the desirable timber species are provided under this system (Trimble 1973). Clearcuts as small as 1 acre (essentially overlapping the group selection system) can be used. Silviculturally there is no upper size limit for clearcuts, but on forests under multiple-use management upper size limits are imposed to enhance wildlife and other values.

Rotation length for maximum wood production is about 70 years for yellow-poplar and 80 for oaks. Most landowners use rotations of 70 to 100 years. The National Forests currently use 100-year rotations to enhance scenic values.

Precommercial thinnings increase growth rate and improve stand composition and stem distribution. Such treatments are costly, however, and gains must be high to justify them. Production of palatable browse may be a partial justification for precommercial thinning (Della-Bianca 1975). On some areas, there is a need to release crop trees from grapevines (McGee and Hooper 1975). Rosebay rhododendron is so dense in some areas that it severely inhibits tree regeneration, but no practical means of control is available (Della-Bianca and McGee 1972).

Stands containing high percentages of yellow-poplar are usually quite dense, and wood fiber yields are highest when these densities are maintained. If the major goal is to enhance growth of saw logs and veneer bolts, however, periodic thinnings are required. A rule of thumb for maximum board-foot growth in thinned stands 30 to 70 years old is to match residual basal area to site index, e.g., 90 square feet basal area on site 90 and so on (Beck and Della-Bianca (1975).

MANAGEMENT IMPACTS AND RECOMMENDATIONS

Goals

If a manager wants to encourage birdlife, his goal should be to provide suitable habitat for each indigenous species for some period during the timber rotation. Further, he should ensure that these sets of conditions are always present at some point in the forest. Any practice that alters vegetation will benefit some species of birds and be detrimental to others. It is impossible to have all bird species nesting in the same stand at the same time, but suitable habitat conditions for each species can be provided in some part of the forest all the time. This approach will provide for more bird species than any attempt to maximize the species and bird density on each acre.

Recommendations for bird management are provided below. These recommendations are based on the best available information. They are, however, largely untested.

Rotation Age

Rotations of 100 years seem adequate to provide habitat for the bird species associated with virgin stands. Specific studies on stand age as it relates to bird communities in cove forests are lacking, but none of the second growth stands reported were greater than 100 years old. Certain species, such as the Black-throated Blue Warbler, Barred Owl, and Pileated Woodpecker may require longer rotations for habitat conditions approaching their optimum.

Shorter rotations of say 70 to 80 years may provide habitat for most, if not all, of the species that were found in virgin stands, but some of these species would probably be existing under marginal habitat conditions that have unknown impacts on the species.

Stand Regeneration

Clearcutting

Clearcuts as small as 1 acre will provide habitat for all the species in table 3 listed under the Second-Growth Sapling Stage except the Prairie Warbler, Yellow-breasted Chat, and Field sparrow. These three species are by far more abundant in the early seral stage of the oak-hickory and oak-pine types adjacent to the cove types so they would not be eliminated from the forest (Hooper 1967).

Larger clearcuts of say 25 acres would provide suitable habitat for larger and less fragmented populations of the early seral species. Birds requiring mature stands would be better provided for, in the long run, by the larger clearcuts since the older stands would also be larger in area. Clearcuts exceeding 30 acres in cove forests seem unnecessary in managing bird populations: all species using sapling and mature stands should find habitat in stands of that size.

Shelterwood Cuts

Shelterwood regeneration areas with a residual basal area of 40 to 50 square feet per acre would probably provide habitat for most of the species of the sapling stage. Species using edge habitats, such as Chestnut-sided Warblers and Indigo Buntings would be especially attracted to shelterwood areas. Some of the species of the mature forest would continue to use the shelterwood area until the residual trees were removed. Due to the layering of the vegetation, a larger number of bird species would be expected on these areas than on the clearcut areas.

Group Selection Cuts

Group selection cuts approaching 1 acre would have effects similar to the smallest clearcuts discussed above. Smaller cuts of 0.25 to 0.50 would probably have effects similar to the individual selection cuts discussed below.

Individual Selection Cuts

Individual selection cuts with a residual basal area of 80 square feet or less per acre and group selection cuts of 0.25 to 0.50 acres would probably result in high densities and numbers of species. Species requiring either a continuous canopy or sparse canopy might be at a disadvantage under these conditions.

Thinnings

Commercial thinnings on these good sites result in prolific growth of the understory (D. E. Beck, pers. commun.). Both the number of species and number of individual birds should increase (Hooper and others 1973) following thinnings.

Thinnings, and possibly individual and group selection cuts, could have a severe impact on the Pileated Woodpecker. Pileated nest trees in Virginia (Conner and others 1975) were on mesic sites and in stands with an average basal area of 137 square feet per acre. Most nest cavities were in dead trees or in dead portions of live trees. Such trees are usually removed in thinnings. Although pileateds have territories of 100 to 200 acres and larger, leaving as little as 1 acre per 100 acres of cove forest unthinned (but regenerated in the normal rotation) could greatly improve conditions for the pileated and other woodpeckers in intensively managed cove forests. Thinning in the usual manner but girdling and leaving several of the less valuable trees might be a more economical alternative.

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A Comparison of Avian Community Structure in the Northern and Southern Appalachian Mountains

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Abstract.--The structure of avian communities along elevational gradients is examined. A descriptive analysis of community-level properties, contrasting northeastern and southeastern communities, is presented. Hypotheses sufficient to explain differences in community organization are proposed and examined by analysis at the population-level. Emphasis is placed on shifts in species habitat utilization subsequent to changes in species composition and habitat availability. Suggestions for the development of workable habitat management schemes are presented.

INTRODUCTION

Numerous studies have recently been conducted in an attempt to understand niche patterns within animal communities, the correlations between various niche dimensions and species diversity, and the contribution of critical dimensions to achieving species coexistence. Many of these studies have dealt explicitly with the importance of habitat usage in ecological communities, particularly bird communities (MacArthur and MacArthur, 1961; MacArthur et al., 1966; Cody, 1968; Wiens, 1969; James, 1971; Shugart and Patten, 1972; Anderson and Shugart, 1974; Whitmore, 1977; and others). Of particular relevance to this symposium is the almost unanimous consensus that bird species diversity is strongly correlated with structural habitat diversity and that for the majority of species there is a cause and effect relationship between these variables.

MacArthur and his coworkers initially established the importance of habitat structure when they discovered the strong positive correlation between foliage height diversity, an index of the vertical distribution of foliage biomass, and species diversity (MacArthur and MacArthur, 1961; MacArthur and Preer, 1962). The major significance of this finding was that a single index was such a powerful predictor of species diversity in a variety of geographically distinct locales.

Following MacArthur, many additional studies aimed at understanding the connection between habitat structure and species diversity have been conducted (reviewed in Balda, 1975). In recent studies there has been a movement away from analyses of single habitat variables towards multivariate analyses of habitat data (i.e., Shugart and Patten, 1972; Whitmore, 1977 The complexity has been expanded primarily for two reasons: 1) to understand bird species diversity patterns in those communities for which foliage height diversity (and other indexes such as percent vegetation cover) had not been a good predictor (i.e., Balda, 1969; Karr, 1971; Pearson, 1975; Willson, 1974); and, 2) to discover the specific features of habitat structure which were contributing to species diversity.

From studies of avian communities occupying temperate forests, some general patterns of resource partitioning have emerged. The most important of these is that habitat selection is the dominant factor determining bird distributions and habitat features are more important than food availability in avian resource division (Schoener, 1974; Shugart et al., 1975). Further, a review of multivariate studies of habitat partitioning in forest bird communities (James, 1971; Shugart and Patten, 1972; Shugart and James, 1973; Anderson and Shugart, 1974; Whitmore, 1975, 1977) reveals a consistently

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dominant role for a small subset of structural habitat variables. The extensive discriminatory power contained in just a few variables is best illustrated by Whitmore (1977) who was able to significantly separate a community of 24 species by considering only 10 habitat variables.

The consistency apparent in these findings indicates that a few structural features of the habitat may be the dominant determinants of species diversity. Further, they argue for a general pattern of forest community organization independent of geographical location within the temperate zone. The unique features of temperate avian species which result in regular patterns of community organization may primarily be a consequence of the migratory nature of the majority of breeders. These characteristics and their implications for the evolution of strong habitat selection have been discussed by Able and Noon (1976).

In the discussion which follows we will examine the organization of eastern montane forest bird communities. We will first present a descriptive analysis of community-level properties, comparing northeastern and southeastern montane communities. From these analyses we generate hypotheses about community structure that are sufficient to explain differences in community-level organization. As a test of our hypotheses we will present results of a population-level analysis of a subset of these avian communities. We examined the ground-foraging thrush guild which, particularly in the Northeast, is a dominant component of these montane communities. We conclude by synthesizing the results of both the community and population-level studies into a tenative scheme for habitat management which, hopefully, will maintain the integrity of natural bird communities.

METHODS

Species Distribution Patterns

On the northeastern and southeastern study sites sampling stations were established approximately every 100m along the elevational gradient. Censusing data was collected during a 3 - 4 hr interval beginning immediately after dawn and again in the late evening 1 - 2 hr prior to sunset. At each sampling station two observers walked in opposite directions recording all bird species seen or heard while progressing at a steady pace for a prescribed length of time (usually .5 - .75 hr). On successive days the order in which stations were sampled was altered so as to minimize bias introduced by time of day. In general, 1.5 - 2 hr of sampling time was accumulated for each sampling station. Finally, the counts were normalized to the number of individuals of each species per hour of sampling time at each station (see Able and Noon 1976, for further details).

Habitat Analyses

The habitat data quantifying the structural parameters of the thrush species' territories were obtained by sampling 0.04 ha (0.1 acre) circular plots centered upon the point at which a bird was seen performing a specified behavior. The sampling methods closely followed quantifications techniques proposed by James and Shugart (1970). The design of the techniques is such that all strata of the forest breeding habitats are thoroughly measured.

A total of 250 habitat quantifications was done on the five thrush species at the northeastern montane site, 94 quantifications were obtained on two thrush species at the southeastern montane site and 56 quantifications were done in a nonmontane site in northern New York. No attempt was made to stay within homogeneous stands of forest when sampling but all samples were collected so as to avoid "edge" situations. All habitat quantifications at both montane sites were done to include habitats covering the full range of a species' elevational distribution. In addition, the sampling intensity, as a function of elevation, reflected the distributional abundance of the species along the elevational gradient.

Study Areas

The northeastern montane study area was Mount Mansfield, the highest mountain in the Green Mountains of Vermont, with an elevation of 1339m. The mountain is located approximately 65 km east of Burlington, Vermont (44° 31'N, 84'W). The study site covers an area of approximately 10 km^2 on the eastern face of the mountain.

Relatively undisturbed forest extends from 550m to 1200m, the last 200m of elevation being alpine meadow and exposed rock. The eastern exposure of the mountain is criss-crossed with numerous ski trails; however, they have had a negligible effect on the composition, abundance and distribution of the avian populations (Able and Noon, 1976). The extent of the edge effect between ski trail and undisturbed forest is slight and we avoided areas of extensive disturbance in all cases. The vegetation of the mountain is basically mature second growth forest, although some areas of virgin spruce-fir remain at high elevations (Siccama, 1968). The mountain is composed of four major vegetation zones. Successively, these zones are: 1) sugar maple (*Acer saccharum*) and beech (*Fagus grandifolia*) forest; 2) yellow birch (*Betula lutea*), paper birch (*B. papyrifera*) and red

spruce (Picea rubens) forest; 3) red spruce and balsam fir (Abies balsami), and 4) alpine tundra.

To the casual observer the mountain gradient appears to consist of at least two discrete vegetational units: pure deciduous and pure coniferous with a zone of mixed vegetation at mid-elevations. However, Siccama (1968) showed that the vegatation of the Green Mountains is actually a complex continuum of species populations rather than a mosaic of discrete communities (see Whittaker, 1967). Deciduous forests characteristic of the low elevation forests are not found above mid-elevations, but species characteristic of upper slopes are found in small numbers on the lower slopes. In the zone between the two major vegetational units species characteristic of both occur, but no species is confined to mid-slope forests. Despite the essential continuity which characterizes the vegetational community of this gradient, we have distinguished three major changes in vegetational physiognomy: 1) the area on the gradient in which beech and sugar maple disappear. Concomitantly, yellow birch and red spruce increase markedly. 2) the virtual disappearance of deciduous trees along with an increase in the proportion of balsam fir. 3) tree line. In practice, ecotones 1) and 2) could be localized within zones of about 100m of elevation or less, and tree line was considerably more abrupt.

The southeastern montane study area was the Great Smoky Mountains National Park located on the border between Tennessee and North Carolina (83° 37'N, 84° 30'W). This montane site covered an elevational gradient extending up to 2025m on Clingman's Dome on the Tennessee side of the main mountain ridge. The gradients studied had primarily a north to north-northwest exposure and for the most part were characterized by mesic to submesic forest types.

The Great Smoky Mountains supports a particularly diverse forest of varied community types. Whittaker (1952, 1956) gave an exhaustive description of the forest communities. In general, the vegetational communities in which studies were done are of three major types: 1) mesic cove forests; 2) submesic oak forests; and 3) subalpine forests.

In the mesic cove forests the principal canopy trees were yellow buckeye (Aesculus octandra), white basswood (Tilia heterophylla), silverbell (Holesia monticola), sugar maple, eastern hemlock (Tsuga canadensis), tulip tree (Liriodendron tulipifera), yellow birch and beech (Whittaker, 1952, 1956). Above 1370m the composition of the mesic forest changes into a subalpine forest dominated by red spruce and Fraser fir (A. fraserii). Outside of the range of the spruce, or where ravines cut into the mountain ridge, mesic stands above 1370m are dominated by gray birch.

In spite of the fact that this transect, like the northeastern one, is also a complex continuum of species and not easily divisible into discrete vegetational communities, two ecotones were recognized: 1) the area on the gradient in which red spruce and yellow birch become significant components of the canopy. This zone is characterized by a substantial decrease in canopy height. 2) the virtual disappearance of deciduous trees along with an abrupt increase in the percentage of red spruce and the appearance of Fraser fir. Both ecotones correspond with areas where gross changes in the structural physiognomy of the forest occurred.

The non-montane northeastern study site included the islands and shoreline areas on the Cranberry Lake Biological Station, Saint Lawrence County, New York (44° 15'N, 74° 45'W). The study site covered an area of approximately 10 km^2.

Relatively undisturbed second growth forest covered most of the areas studied, though some areas of virgin forest were also included. The range of forest types and vegetational dominants encountered in this region were very similar to those on Mount Mansfield with the notable absence of extensive stands of balsam fir and stunted coniferous vegetation. Elevation at this study site ranged from 450 - 550m.

RESULTS

Community Patterns

Species Composition

We have previously described the community structure patterns on four mountains in New York and Vermont (Able and Noon, 1976). There were great similarities among the four gradients; for this comparison we have used data only from Mount Mansfield, Vermont, the gradient we studied most extensively.

The Mt. Mansfield and Smoky Mt. elevational gradients encompassed a similar (structural) range of forest habitats and each gradient had the same number of species, 41. There were, however, considerable differences in the species composition on the two transects; they overlapped in slightly less than two-thirds of their species. Sixteen species (39 percent of the total) on the Smoky Mt. gradient were not present on Mt. Mansfield (Com. Flicker, Colaptes auratus; Pileated Woodpecker, Dryocopus pileatus; Acadian Flycatcher, Empidonax virescens; Carolina Chickadee, Parus carolinensis; Tufted Titmouse, P. bicolor; Carolina Wren, Thryothorus ludovici-

anus; Blue-gray Gnatcatcher, Polioptila caerulea; Yellow-throated Vireo, Vireo flavifrons; Worm-eating Warbler, Helmitheros vermivorus; Cerulean Warbler, Dendroica cerulea; Yellow-throated Warbler, D. dominica; Chestnut-sided Warbler, D. pensylvanica; Louisiana Waterthrush, Seiurus motacilla; Kentucky Warbler, Oporornis formosus; Hooded Warbler, Wilsonia citrina; Cardinal, Richmondena cardinalis). Fourteen species (34 percent) absent on the Smoky Mt. gradient were found on Mt. Mansfield (Least Flycatcher, E. minimus Raven, Corvus corax; White-breasted Nuthatch, Sitta carolinensis; Hermit Thrush, C. guttatus; Swainson's Thrush, Catharus ustulatus; Gray-cheeked Thrush, C. minimus; Cedar Waxwing, Bombycilla cedrorum; Nashville Warbler, Vermivora ruficapilla; Yellow-rumped Warbler, coronata; Blackpoll Warbler, D. striata; Mourning Warbler, O. philadelphia; Common Yellowthroat, Geothlypis trichas; Purple Finch, Carpodacus purpureus; White-throated Sparrow, Zonotrichia albicollis). Many of these differences between the two localities involved abundant and broadly distributed species. When one considers a spectrum of habitats such as occurs on these elevational gradients, the southern avifauna cannot be considered an included subset of the northern as Rabenold (1976) found when only spruce-fir forests in the two areas were examined.

Figure 1 compares patterns of species diversity on the two gradients. Species richness and two indices of diversity are plotted. In both regions, the three measures of diversity tend to be highly correlated, but there are obvious differences in pattern. On Mt. Mansfield both diversity indices closely parallel the trend in species richness and all generally declined with elevation. In the Smoky Mountains, species richness fluctuated greatly but still showed a downward trend with elevation. N_1 and N_2 also showed considerable variation over the length of the gradient, but if a trend similar to that of species richness is present it is very slight. The relative flatness of the diversity curves is in marked contrast to those for Mt. Mansfield.

Because the species richness of the Smoky Mt. communities is essentially the same as on Mt. Mansfield the marked differences in diversity must be due to differences in equitability. This can be seen graphically in Fig. 2 which compares dominance-diversity curves for the two gradients. The Smoky Mt. communities are characterized by much higher dominance and a greater increase in dominance over the span of habitats relative to Mt. Mansfield. Figure 3 presents an analysis of dominance comparing the Smoky Mt. communities with those on Mt. Mansfield and nearby Camel's Hump Mt. by Wiens' (1975) method. For a community with a given number of species, the samples from the Smoky Mts. had significantly higher dominance ($p<.025$; Mann-Whitney, one-tailed) than the two northern mountains.

The overall difference in dominance in the two regions appears to be due to higher relative abundances of the commonest one or two species in the Smoky Mt. communities rather than to a difference in numbers of rare species. This can be seen in Table 1 which ranks the relative abundances of the four commonest species at selected elevations on the two mountains. At all but one of these sampling stations, the dominant Smoky Mt. species had much higher pi's than their northern counterparts. Mean proportional abundances of all the species comprising

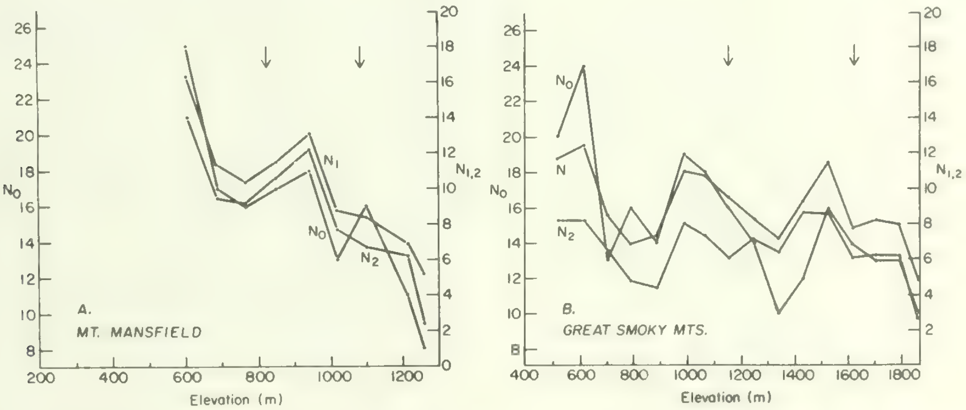

Figure 1.--Plots of species richness (N_0) and diversity with elevation on Mt. Mansfield, Vermont (A) and Great Smoky Mountains (B). $N_1 = \mathrm{Exp}(H')$; $N_2 = 1/\Sigma p_i^2$.

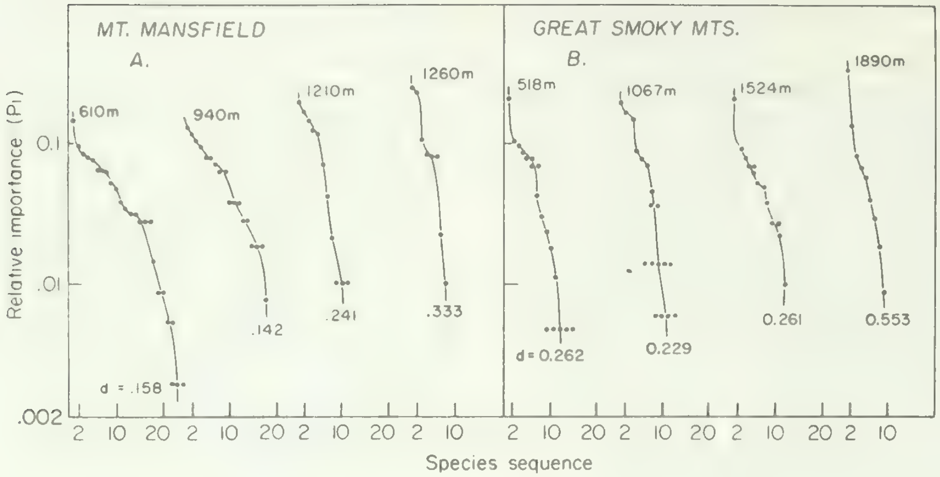

Figure 2.--Dominance-diversity curves for selected elevation on Mount Mansfield, Vermont (A) and Great Smoky Mountains (B). Each species is represented by its proportional abundance in the sample (p_i) on the ordinate, and its rank in the sequence of species from the most to the least abundant on the abcissa. Indices of dominance, $d = N_{i_{max}}/N$, are given for each curve.

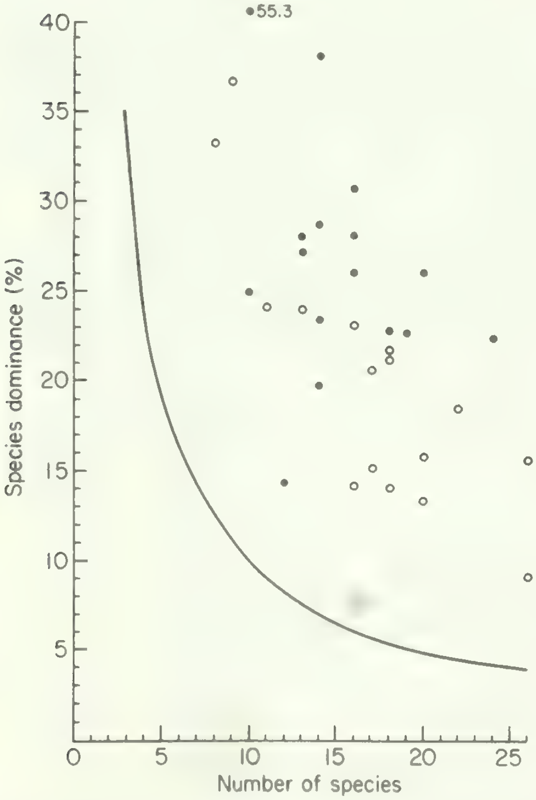

Figure 3.--Comparison of degree of dominance for given numbers of species in communities on Mount Mansfield and Camel's Hump Mountain, Vermont.

a census was always higher and generally more variable on Mt. Mansfield than in the Smokies.

The major differences in species composition between the two regions precluded a paired comparison, but the abundances of the less common species were generally similar. The great difference in dominance was largely due to the much greater nos. of the most abundant species. As a result of this, nearly all elevations in the Smoky Mts. supported a significantly larger number of individuals than comparable sites on any of the northeastern gradients (mean no. indivs./hr., all stations, Smoky Mts. = 170.7, S.D. = 28.3; Mt. Mansfield $\bar{X}$ = 100.0; S.D. = 33.5; Whiteface Mt. $\bar{X}$ = 148.4; S.D. = 55.7).

Species Amplitudes

On both northern and southern elevational gradients a few species with very generalized habitat preferences were found over nearly the entire transects (Table 2). In the Northeast, the Dark-eyed Junco (*Junco hyemalis*) and White-throated Sparrow ranked among the top five species on all four mountains (Able and Noon, 1976). Three of the six broadest species on Mt. Mansfield were among the five broadest in the Smoky Mts. In addition, the Black-throated Green Warbler (*Dendroica virens*) ranked fifth on Whiteface Mt. in the Adirondacks of New York. Thus there appears to be considerable similarity in the amplitude patterns of the habitat generalists in the two regions.

able 1.--Ranking and proportional abundances of the four most abundant species at selected elevations on Mount Mansfield, Vermont, and the Great Smoky Mountains. Mean p_i values for all species at each elevation are also given.

pecies	p_i	Species	p_i	Species	p_i	Species	p_i
ount Mansfield							
l. 610m		770m		1020m		1260m	
ed-eyed Vireo	.1573	Red-eyed Vireo	.1770	Blackpoll Warbler	.2353	Wh.-thr. Sparrow	.3333
mer. Redstart	.0941	Dark-eyed Junco	.1416	Wh.-thr. Sparrow	.1765	Blackpoll Warbler	.2941
venbird	[illegible]	Amer. Robin	.1416	Winter Wren	.1029	Nashville Warbler	.1078
ood Thrush	.0754	Hermit Thrush	.1327	Swainson's Thrush	.1029	Yel.-rump. Warbler	.0784
i	[illegible]		.0625		.0769		.1250
.D.	.0362		.0555		.0664		.1214
reat Smoky Mountains							
l. 610m		976m		1524m		1798m	
ed-eyed Vireo	.2706	Red-eyed Vireo	.2258	Dark-eyed Junco	.2611	Dark-eyed Junco	.2896
venbird	.1832	Bl.thr.Blue War.	.1935	Veery	.0887	Gold.-cr.Kinglet	.1639
l.-thr.Green War.	.1353	Bl.thr.Green War.	.0774	Bl.-cap.Chickadee	.0887	Bl.-thr.Green War.	.1585
mer. Redstart	.1000	Ovenbird	.0701	Blackburnian War.	.0887	Solitary Vireo	.1148
i	.0392		.0490		.0625		.0716
.D.	.0558		.0599		.0598		.0837

able 2.--Elevational amplitude rankings of the five species on each mountain with the broadest distributions on the gradients.

mplitude Rank	Mount Mansfield			Great Smoky Mountains		
	Species	Amplitude (m)	Proportional Amplitude	Species	Amplitude (m)	Proportional Amplitude
1	Dark-eyed Junco	660	.943	Hairy Woodpecker	1372	.994
2	Winter Wren	660	.943	Amer. Robin	1372	.994
3	Bl.-cap.Chickadee	610	.871	Bl.-thr.Green War.	1372	.994
4	Wh.-thr. Sparrow	495	.707	Solitary Vireo	1098	.796
5	Hairy Woodpecker	495	.707	Dark-eyed Junco	1098	.796
6	Amer. Robin	495	.707			

In general, species in the Great Smoky Mts. occupied a larger proportion of the elevational gradient. However, in both areas a few species whose distributions appeared not to be artificially truncated by the ends of the gradient were nonetheless characterized by very narrow ranges. In the Northeast, the Golden-crowned Kinglet (Regulus satrapa) and Canada Warbler (Wilsonia canadensis) were found in the middle elevations, but had narrow amplitudes of between 100-150m (about 18 percent of elevational range). In the Smoky Mts., the Kinglet was again among the narrowest species with an amplitude of about 275m (about 20 percent of elevational range) and Brown Creeper (Certhia familiaris) was similar.

In both regions, the mean amplitude of the species at each sampling station increased with elevation and decreased with species richness (Fig. 4). These relationships say that the high elevation faunas of these mountains are made up largely of habitat generalists which dominate the depauperate communities at the tops of the mountains. The high elevation community is basically a subset of lower elevation avifaunas and at high elevations the most abundant species attained both greater dominance and absolute abundances than lower elevation dominants. Among all species on the gradients there is a positive correlation between amplitude and abundance (Able and Noon, unpubl. data). Of the 10 most numerous species, all but two also ranked among the 10 species with the largest amplitudes on the gradient.

Community Structure

Patterns of species turnover on environmental gradients can give insight into mechanisms producing community structure. We have examined the similarity of species composition and relative abundance at sampling stations along the gradients using a dissimilarity index (MacArthur, 1972, p. 189):

$$M = \frac{2}{1 + \dfrac{2\Sigma p_i q_i}{\Sigma {p_i}^2 + \Sigma {q_i}^2}},$$

where p_i and q_i are the proportions of species i in samples p and q, and $1 \leq M \leq 2$. Figure 5 compares Mt. Mansfield and the Smoky Mts. by plotting the similarity between the lowest stations and each successively higher station. In general, the functions should increase as the distance between stations being compared increases. An increase in the slope of the line indicates a greater change in community composition between two stations.

On the four mountains studied in the Northeast, increases in dissimilarity (i.e., increases in M) were associated with ecotones. Mt. Mansfield, the steepest of the four, was slightly atypical in that the two ecotones appeared to have been treated as a single discontinuity, at least as far as our analysis was able to discriminate. The pattern on the Smoky Mt. elevational gradient was very similar, with a very large and abrupt faunal change between the stations at 1067m and 1158m. The data from both areas suggest a major influence of habitat discontinuities in determining the distributional limits of species on these gradients. Whereas there are obvious and large changes in species composition and relative abundances on the Smoky Mt. transect, the magnitude of the effect is not as great at the species level as in the Northeast (Table 3). Only about one-third of the species' distributional limits coincided with ecotones in the Smoky Mts. compared with slightly more than half of such limits in the Northeast. In fact, the proportion of species limits associated with ecotones in the Smokies does not differ from that found by Terborgh (1971) in Peru (with data normalized for number of sampling stations associated with ecotones). However, ecotones still exerted a large effect in the Smokies through changes in relative abundances.

In our earlier paper (1976) we failed to find any evidence of overt competitive exclusion in the distribution patterns of the species. Further detailed studies of the five thrushes on these gradients has also failed to reveal any interference competition (e.g., interspecific territoriality) (Noon, 1977). In the Great Smoky Mts., cases suggestive of spatial competitive exclusion were even rarer. The Wood Thrush (Hylocichla mustelina) and Veery (Catharus fuscescens) and the Red-eyed (Vireo olivaceus) and Solitary Vireos (V. solitarius), as well as a host of parulid species, overlapped broadly on the gradient. Among congeners, only the Carolina (Parus carolinensis) and Black-capped Chickadees (P. atricapillus) were continguously allopatric, although neither reached near maximal abundance adjacent to the contact zone. Thus with respect to evidence of interspecific competition in the form of intra-habitat spatial exclusion, the pattern in the Smokies appeared to be virtually identical to that in the Northeast.

The species comprising the breeding avifaunas of both regions are predominantly migratory, inhabiting these forests only during the relatively short breeding season. There are, however, noticeable differences between the two areas with respect to the proportions of species and individuals that are long-distance migrants. About three-fourths of the species included in our censuses of New England mountains are migrants that leave the region in winter. In the Smoky Mts. only 62 percent of the species make migrations more extensive than short-distance altitudinal movements. A much more striking

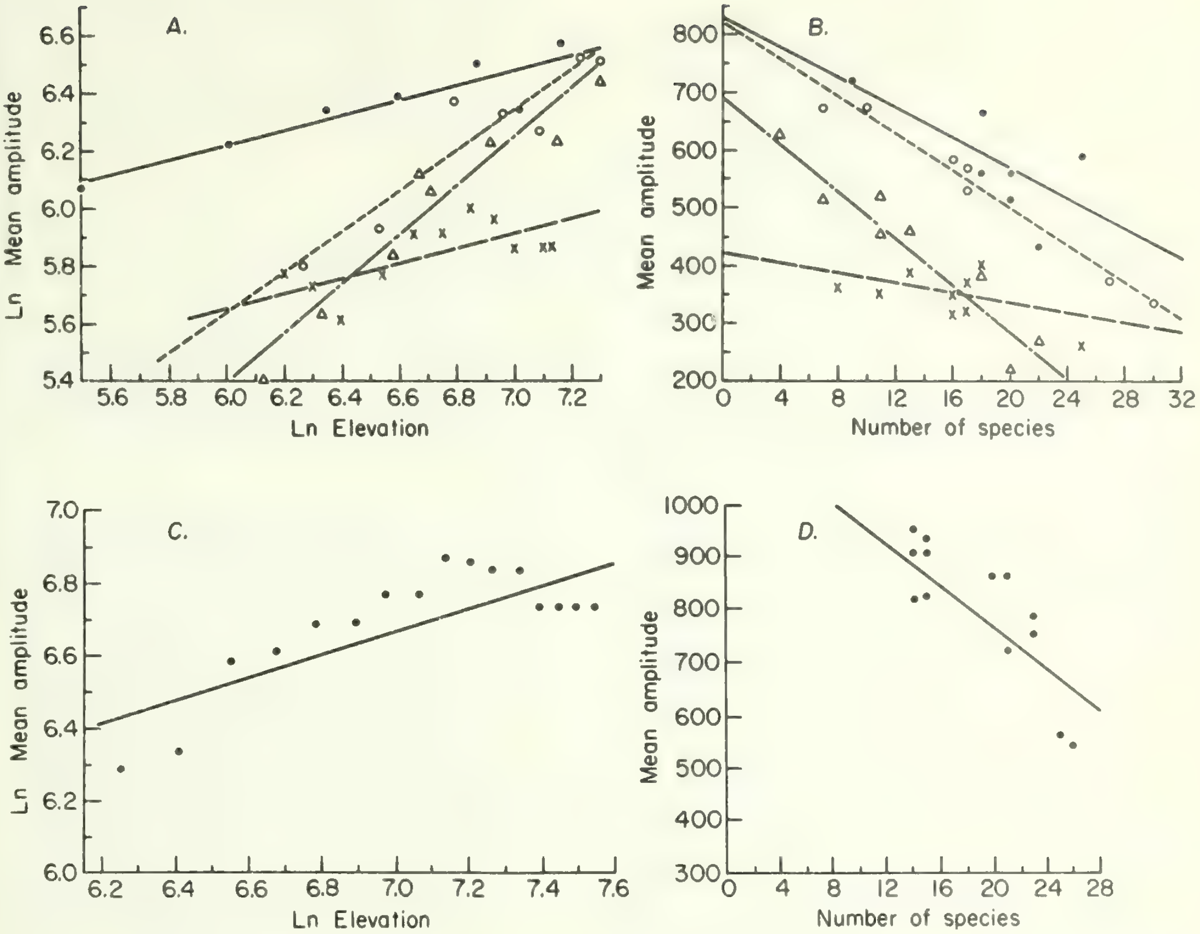

Figure 4.--Regressions of mean species amplitude at given sampling stations on elevation and the species richness at the station. A and B, northeastern mountains: X Mount Mansfield; • Camel's Hump Mountain; 0 Whiteface Mountain, New York; Δ Nippletop Mountain, New York. C and D, Great Smoky Mountains.

difference can be seen if one compares proportions of individuals that belong to essentially resident species. On Mt. Mansfield, this figure varies between about 12 percent (lowest elevation sampled) and 2 percent (highest station) (mean = 7.2 percent). In contrast, the proportion of individuals belonging to resident species ranged from about 4 percent (884m station) to 66 percent (highest station) (mean = 29.7 percent) and generally increased with elevation.

The difference between the two regions was due almost entirely to the high importance of Dark-eyed Junco, Black-capped Chickadee, Golden-crowned Kinglet and Red-breasted Nuthatch above the first ecotone at around 1160m. In general, resident species did not reach higher abundance nor did they have larger amplitude than migrants (some examples are shown in Table 1).

Population Patterns

Northeastern Montane

Distributional Analyses.-- A particularly interesting pattern of our northeastern montane censuses was the diversity of thrush species (Hylocichla and Catharus) occupying these

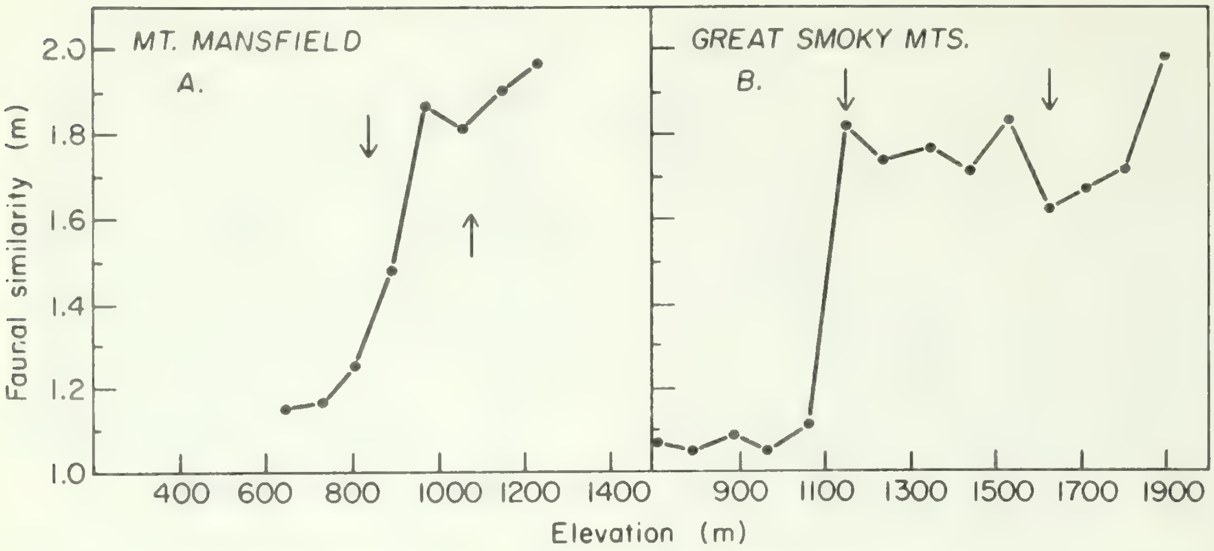

Figure 5.--Plots of the index of faunal dissimilarity (M) between the lowest elevation station and each succeeding higher one on Mount Mansfield (A) and between the lowest two stations combined and each succeeding higher one in the Great Smoky Mountains (B).

Table 3.--Elevation limits of species distributions in relation to ecotones on five mountains.

Mountain	No. of limits excluding termini	No. at ecotones	Proportion at ecotones	Proportion of limits/ ecotone station
Whiteface (NY)	35	20	0.570	0.285
Nippletop (NY)	34	18	0.530	0.177
Mansfield (VT)	39	20	0.510	0.170
Camel's Hump (VT)	39	20	0.510	0.255
Gr. Smoky (Tenn.)	40	13	0.325	0.081

gradients. When the relative abundances of the four most abundant species at each sampling station were calculated, one or more thrush species ranked in the top four at the majority of sampling sites. Figure 6 illustrates the distributional patterns of the thrush species on Mount Mansfield. Plotted are abundances, normalized and expressed as the number of individuals of species *i* censused per hour. The patterns illustrated here were qualitatively similar for all four northeastern elevational gradients.

From the figure it is apparent that the Wood thrush and Veery had very similar distributions being most abundant at low elevations and reaching their upper limit together at the lower ecotone. The Hermit thrush bred at low elevations but showed variable abundance, extending beyond the lower ecotone into mid-elevations. At higher elevations the Swainson's and Gray-cheeked thrushes inhabited mutually ex-

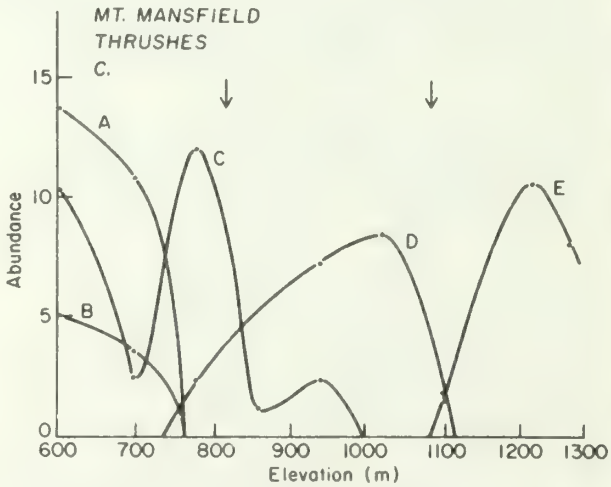

Figure 6.--The abundances of the thrush species on the Vermont elevational gradient, species of thrushes are denoted as: (A) Wood thrush; (B) Veery; (C) Hermit thrush; (D) Swainson's thrush; (E) Gray-cheeked thrush.

clusive ranges. The Swainson's thrush overlapped extensively with the hermit thrush at the lower end of its distribution, but had mimimum overlap with the gray-cheeked at its upper extent. The truncated distributions of these two species at their zone of contact suggests interference competition except that this point coincided with the upper elevational ecotone.

Habitat Analyses.--During the breeding seasons of 1975 and 1976, habitat quantifications were done for the five thrush species breeding on Mount Mansfield. Fifty habitat quantifications were done for each species with each quantification consisting of measurements on 58 structural habitat variables (details given in Noon, 1977). Each species was represented in the data matrix by 50, 58-element observation vectors.

Univariate analyses (one-way analysis of variance) of the structural habitat variables revealed patterns of intrahabitat separation for overlapping species and interhabitat separation for species with disjunct elevational distributions. Each of the variables measured was regarded as a continuous gradient quantifying some aspect of the breeding territories selected by these species. Overlap was extensive along most of these gradients, but all species showed patterns of separation along a unique complex of variables. Simultaneous differences along a multitude of gradients resulted in a significant increase in separation. However, many of the variables measured were highly correlated, and the danger of achieving a distorted picture of the nature and extent of group differences increases as the correlations among the variables increases.

An alternative way to describe group differences is to use discriminant function analysis which constructs a linear combination of the set of variables that will maximally discriminate the groups. The linear combination is a new, transformed variable composed of the original variables each weighted according to its power to distinguish the groups. Species' positions are then examined in terms of their ranking along this linear combination. By this process, species' positions on several independently measured univariate gradients (which may be highly redundant) are reduced to a single position along a multidimensional gradient of habitat structure. This reduction in dimensionality simplifies elucidation of species' differences and facilitates quantitative comparisons among the species in terms of a few highly significant variables. For an indepth discussion of the applications of discriminant analysis to ecological problems see Green (1971, 1974).

The use of discriminant function analysis as a powerful tool for forest managers was proposed at a previous meeting of this group by Shugart et al. (1975). The specific advantage of this type analysis is that it reduces complex multivariate data to a manageable and significant subset of the original data. In addition, it goes beyond ambiguous univariate correlational studies (such as the relationship between foliage height diversity and bird species diversity) to identify specific features of habitat structure strongly correlated with a species' presence.

The results of multiple step-wise discriminant analysis of the thrush guild are presented in Table 4. The number of variables needed to significantly distinguish the structural habitats of these species has been reduced from over 50 to nine. A test of the discriminatory power of the subset of nine variables prior to the removal of any discriminant functions indicated that they contained a highly significant amount of discriminatory power (Wilk's lambda = 0.0379; associated chi-square = 792; $p<.001$). In addition, 96 percent of the variability in the predictor variables can be explained by group differences (ω^2 multi = 96).

The proportion of the discriminatory power contained in the subset of predictor variables attributable to the ith discriminant function is given by the ratio: $P_i = \lambda_i / (\lambda_1 + \lambda_2 + \ldots \lambda_n)$. where λ = the eigenvalue of the ith discriminant function. P_i is an index of how the total discriminatory power of the predictor variables is apportioned to each discriminant function. Thus, 85 percent of the discriminatory power of the predictor variables is accounted for by the first discriminant function, 7.9 percent by the second, and so on. The discussion which follows confines itself to an analysis of the first two functions which collectively account for over 90 percent of the discriminating power contained in the analysis.

Additional information essential for an understanding of the analysis are the standardized discriminant function coefficients given opposite each variable in the table. The absolute value of each coefficient is proportional to the relative contribution of its associated variable to group separation along that discriminant axis. The sign merely indicates whether the variable is making a positive or negative contribution. These coefficients may be used to interpret the functions by identifying the dominant characteristics by which separation occur.

The positions of the species' mean habitat vectors in discriminant two-space, as well as the 95 percent confidence limits around these points, are shown in Fig. 7. The relative

Table 4.--Summary of Multiple Stepwise Discriminant Analysis

	Discriminant Function			
Characteristic:	I	II	III	IV
Eigenvalue	7.94	0.736	0.395	0.220
Relative percentage of eigenvalue associated with the function	85.5	7.90	4.3	2.3
Cumulative percentage of eigenvalue across all discriminant functions	85.5	93.4	97.7	100.0
Chi-square statistic for testing significance of discriminant function	792.0	262.0	129.0	48.0
Significance (degrees of freedom)	$p << .001$ (36)	$p << .001$ (24)	$p << .001$ (14)	$p << .001$ (6)
Standardized Discriminant Function Coefficients				
CPCR	.4877	-.8273	.0134	1.3435
GDCR	-.0322	-.4870	-.4177	-.0701
RDBA	.1205	-.2947	-.6126	.0099
USCF	-.1224	-.4182	-.7317	-.1562
ADDC	.0766	.5365	-.2234	.0055
TALL	.2309	-.7188	.3561	-.6737
SBDY	.0110	-.6947	.6158	.3175
NOTS	.9431	-.3890	-.3571	-.1726
AVDI	.0131	.1559	-.0105	-1.0300

ADDC - absolute density of deciduous trees
AVDI - average diameter of trees
CPCR - percent canopy cover
GDCR - percent ground cover
NOTS - number of tree species
RDBA - relative basal area of deciduous trees
SBDY - shrub density
TALL - canopy height
USCF - percent of understory coniferous

positions of the group centroids reflect individual responses to structural niche variables as well as the difference among the species in their response to habitat gradients. The magnitude of the distances separating species in this plane reflects the degree to which their habitat selection patterns differ. The further apart any two species' mean observation vectors are in this space, the less similar are their structural niches.

To understand the manner in which significant segregation is achieved and the contribution of each variable to separation, it is instructive to look at each discriminant axis independently (Fig. 8).

Canopy cover (CPCR), canopy height (TALL), and percent understory coniferous (USCF) were the dominant variables describing DF-I. The function is in effect a gradient reflecting canopy features and the deciduous to coniferous continuum which parallels the gradient of elevation. The discriminant function represents a macrohabitat description of the change in forest structure and composition as one proceeds from low to high elevations. The extremes of this gradient are occupied by habitats selected by the Wood thrush and Gray-cheeked thrush. The habitats selected by the Wood thrush are characterized by high canopy cover and height and low percentage of coniferous understory, whereas the Gray-cheeked

thrush selects stunted spruce-fir forests where the relative magnitudes of these variables are reversed. Species positions along this discriminant axis are consistent, and in the same sequential order as, their distributional pattern along the elevational gradient. For example, the Gray-cheeked thrush is widely separated from all other species which in turn are clustered along the positive portion of the axis. The Wood thrush and Veery have almost coincident centroids on this axis reflecting their complete overlap along the elevational gradient. Extensive overlap occurs because variables reflecting interhabitat differences are unable to discriminate these two species.

Canopy cover and height were again the most dominant variables characterizing DF-II, but in addition, shrub density (SBDY) and the absolute density of deciduous trees (ADDC) contributed substantially to group separation along this axis. The pattern of covariance among these variables describes a gradient of habitats from those characterized by relatively high canopy cover and height, dominated by deciduous trees, to habitats of dense shrubs with an open and often low canopy. Species' positions along this gradient are again interpretable in terms of the continuum of forest types which characterize the species' elevational distributions, but, in addition, variables reflecting intrahabitat separation are important for group discrimination. For example, the relative positions of the Wood thrush and Veery centroids are significantly separated along this axis primarily because of the contribution of shrub density. The most extensive separation occured between the Swainson's and Hermit thrushes

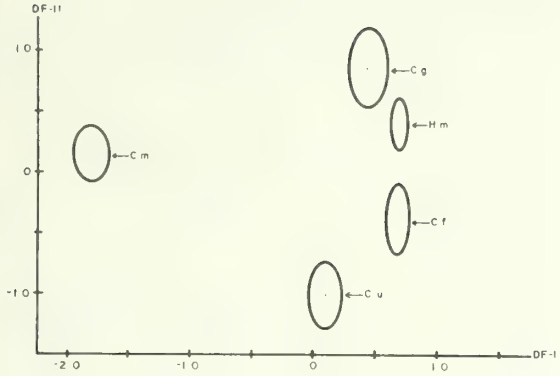

Figure 7.--95 percent confidence ellipses about the means on DF-I and DF-II for the five northeast thrush species. Species of thrushes are denoted as: (H.m.) Wood thrush; (C.f) Veery; (C.g) Hermit thrush; (C.u.) Swainson's thrush; (C.m.) Gray-cheeked thrush.

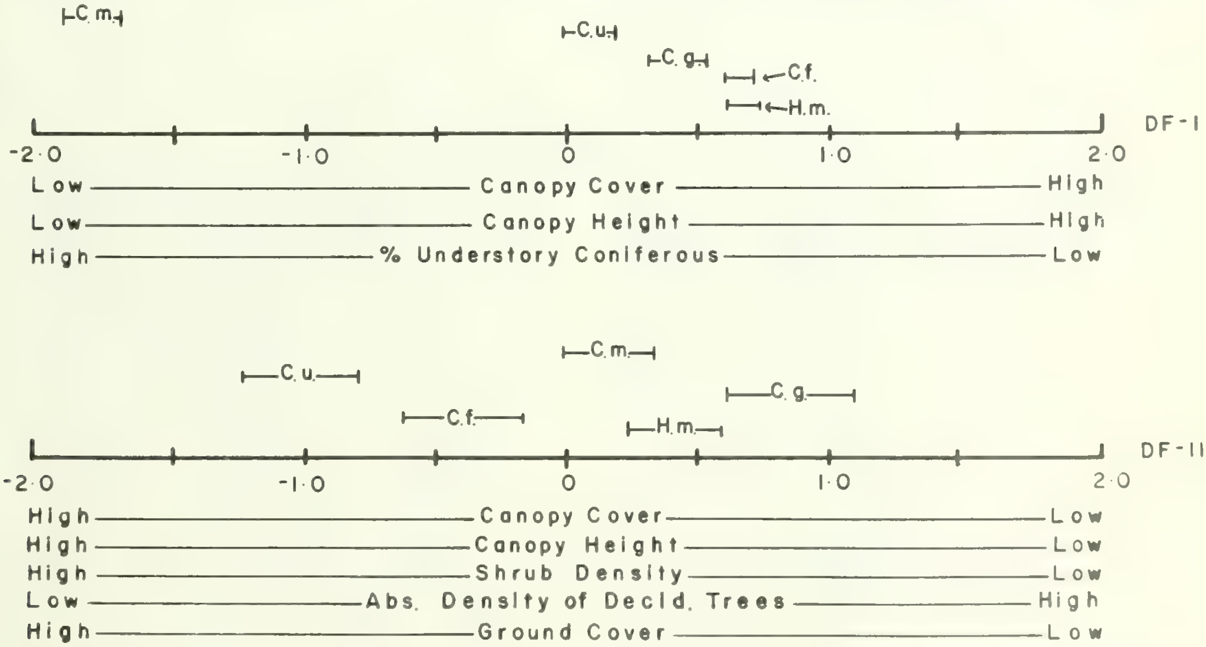

Figure 8.--Thrush species positions on each independent discriminant axis. Species denoted as in Fig. 7.

primarily because of the influence of shrub density coupled with ground cover: both microhabitat variables reflecting the mosaic structure of the habitat in the area in which these species overlap.

The most direct way to test the discriminating power of the variables selected by the analysis is to determine their effectiveness at accurately assigning the observations to the correct species' group. If a large number of misclassifications occur, then the variables selected are poor discriminators. In practice, the actual and predicted group membership results are compared for those observations actually used to derive the functions. The power of the discriminating variables is empirically determined by the proportion of correct classifications. The results for the five northeastern thrush species are summarized in the classification matrix given in Table 5.

By employing a subset of nine of the original 50 structural variables over 77 percent of the 250 individual quantifications have been assigned to the correct species' group. The accuracy of assignment varies among the species and this in turn supplies information on the degree of ecological similarity of the various species pairs. The number of groups to which a species is misclassified and the extent of this misclassification is a crude index of habitat niche breadth for the species. For example, of the five species considered here the Hermit thrush occupies the widest range of habitat types and thus would have the largest niche breadth.

From the perspective of habitat assessment the results presented here indicate that by quantifying just nine structural habitat variables, the forest manager could predict with 77 percent accuracy what thrush species occupies a particular patch of forest. Of course this statement may need to be qualified because this pattern of habitat selection may be unique to northeast montane forests or, perhaps, solely to Mount Mansfield. In order to develop a workable management scheme to increase the breeding status of the Veery, for example, it is necessary to test the generality of the habitat selection model developed from the Mount Mansfield study area. For avian species, an assessment of their habitat associations in vegatationally similar communities, adjacent and geographically distinct, would constitute a powerful test of their generality of habitat selection. To this end we performed identical habitat analyses of thrush species in the Smoky Mountains and in non-montane areas in northern New York State. In essence, we will test the accuracy with which the classification functions (based on the nine discriminating variables) derived from the Vermont study assign thrush individuals breeding in other locales to their correct species group. The proportion of correct classifications is an empirical index of the generality of their habitat selection.

Southern Montane

Distributional Analyses.--During May 1977 an extensive elevational transect on the Tennessee side of the Great Smoky Mountains National Park was censused. As discussed earlier, the census results included information on the

Table 5.--Classification Matrix

		Predicted Group Membership				
Actual group	N	Wood thrush	Veery	Hermit thrush	Swainson's thrush	Gray-cheeked thrush
W.T.	50	78% (39)	14% (7)	8% (4)	0% (0)	0% (0)
Vy.	50	22% (11)	66% (33)	8% (4)	4% (2)	0% (0)
H.T.	50	22% (11)	2% (1)	62% (31)	14% (7)	0% (0)
S.T.	50	4% (2)	10% (5)	0% (0)	84% (42)	2% (1)
G.C.T.	50	0% (0)	0% (0)	0% (0)	2% (1)	98% (49)

Percent of observations correctly classified: 77.6%

species composition and distributional patterns of these montane avian communities. At all sampling stations thrush species were a significant component of the species complement. The Wood thrush generally had lower relative absolute abundance than on northeastern gradients while the Veery had comparable abundance (Fig. 9). Some of the decrease in the Wood thrush density may be attributable to time of sampling. The early spring of 1977 was unusually warm and the species may have been sufficiently advanced into its breeding cycle as to be vocalizing less frequently.

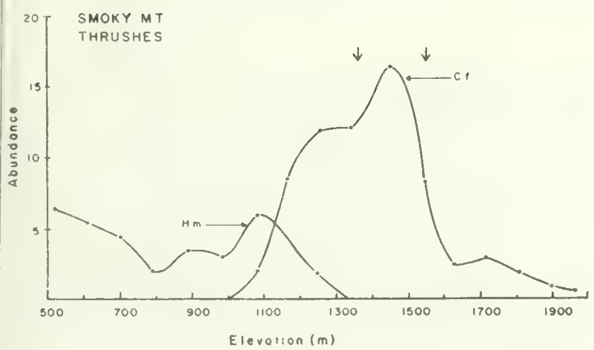

Figure 9.--The abundances of the thrush species on the Smoky Mountain elevational gradient. Species denoted as in Fig. 7.

Note from Fig. 9 that the Wood thrush distribution pattern in the Southeast was comparable to the northeastern pattern. It occupied the lower altitudes along the gradient and its upper elevational terminus coincided with the lower ecotone as on Mount Mansfield. However, the distribution pattern of the Veery was markedly different. It did not appear on the gradient until mid-elevations (but below the first ecotone) and extended all the way to the upper terminus of the gradient. Unlike their northeastern distributions, the Wood thrush and Veery tended to inhabit mutually exclusive ranges along southeastern mountains. In addition, both species showed evidence of amplitude expansion. The Wood thrush and Veery occupied 37 percent of the northeastern gradient but occupied 56 percent and 68 percent respectively of the southeastern transect.

Habitat release indicates shifts in a species' structural habitat niche to include areas of niche space occupied by putative competitors in sympatry (e.g., Crowell, 1961, 1962; Diamond, 1970; Yeaton, 1974; Terborg and Weske, 1975; and others). The amplitude expansion and elevation distributional patterns of the two southeastern thrush populations, particularly the Veery's shift to high elevations, implies that habitat release has occurred for these species. However, to convincingly argue that release has occurred, it is necessary to establish that niche shifts have occurred along critical niche dimensions. Optimally, these will be dimensions quantifying proximate cues used to assess habitat suitability. Operationally, they are usually dimensions derived from multivariate statistical analyses and thus potentially both highly correlated with and powerful predictors of a species' presence.

Habitat Analyses.-- To rigorously test the specificity of the species' habitat selection, and thus the generality of our model, each of the southeastern observation vectors were individually classified by their highest probability of species membership. By classification is meant the process of identifying the likely group membership of an observation vector according to its values on the discriminating variables. Classification is achieved through the use of linear classification equations derived during discriminant analysis from the pooled within-groups covariance matrix and the centroids for the discriminating variables (Klecka, 1975). A separate equation is derived for each group in the analysis. The classification score for each observation for each group is determined by multiplying the raw variable values by their associated coefficients, and adding these together along with the group constant. The observation is then assigned to the species group with the largest classification score.

The results of the classification of the southeastern Wood thrush and Veery populations, according to the functions derived from the northeastern guild, are presented in Table 6. Only 45 percent of the Smoky Mountain Wood thrush individuals were classified as selecting habitats structurally comparable to their northeastern counterparts. Contrast this value with the 78 percent correct classification for northeastern Wood thrushes. Smoky Mountain Wood thrush most frequently select habitats like those selected by northeastern montane Veeries.

Fifty-one percent of the southeastern Veery observation vectors have structural niche configurations consistent with their northeastern conspecifics. Thirty-two percent of the population selected habitats structurally comparable to those selected by the Swainson's thrush, whereas only four percent of the population selected habitats of this type on Mount Mansfield. This represents a substantial expansion

Table 6.--Classification of Smoky Mountain observation vectors by Mount Mansfield classification functions.

		Predicted Group Membership				
Actual Group	N	Wood thrush	Veery	Hermit thursh	Swainson's thrush	Gray-cheeked thrush
W.T. (S)	47	45% (21)	49% (23)	4% (2)	2% (1)	0% (0)
Vy. (S)	47	8.5% (4)	51% (24)	8.5% (4)	32% (15)	0% (0)

into the habitat types which are not utilized in the presence of the Swainson's thrush.

The extensive habitat release observed for both these species suggests a strong role for interspecific competition in shaping the specific habitat selection patterns detected for the northeastern montane populations (see Noon, 1977). The most pertinent issue relative to the topic of this paper, however, is the lack of consistency in structural habitat selection between these geographically distinct montane thrush populations. Changes in a species composition as well as structural habitat may result in significant shifts in habitat utilization. The model of habitat selection generated from the study of northeastern montane thrush populations cannot be generalized to vegetationally similar southeastern montane forests. Development of habitat management scheme for forest species may become greatly complicated because of niche shifts which accompany changes in a species' biotic environment.

The niche shifts observed in southeastern thrush populations may have been predicted to some extent because of potential genetic and/or phenotypic differences in populations occupying opposite extremes of the species distributions. In addition, there may be subtle structural changes in forest physiognomy which precludes the species selecting identical structural habitats at these two geographically distinct areas. However, foliage height diversity profiles for spruce-fir forest in northern Maine and the Smoky Mountains are almost identical (Rabenold, 1976), indicating the structural differences may be slight.

To more rigorously test the generality of the habitat selection model established from Mount Mansfield, we studied thrush populations at a comparable latitude but occupying non-montane forests. This comparison may control for significant genetic or phenotypic population differences as well as subtle structural differences in vegetation structure. This study area was occupied by all of the northeastern montane thrush species except the Gray-cheeked thrush. The methods of locating individuals and quantifying their breeding territories were identical to those previously employed.

The classification results for the 56 habitat quantifications are presented in Table 7. All thrush species, except the Swainson's thrush, are predominantly classified into their correct species group. However, the accuracy of classification has dropped substantially for most species, particularly for the Swainson's thrush which is strongly misclassified as Wood thrush. The pattern of misclassification for the Swainson's thrush is particularly surprising because this species and the Wood thrush show virtually no spatial overlap on any of the northeastern elevational gradients (Able and Noon, 1976). The results imply that the habitat selection model cannot be readily applied to adjacent non-montane axes.

We propose two tenative hypotheses to explain the lack of generality in habitat selection for these thrush populations. The first of these concerns the distribution of vegetational patches with particular structural attributes. Habitat patches with the appropriate structural configuration for a specific thrush species appear to be smaller in spatial extent and more randomly distributed in the Cranberry Lake region than on adjacent mountains. This difference between montane and non-montane areas is most likely the result of stricter vegetational zonation on mountains; a consequence of rapid change in abiotic influences which control plant species distributions. If the species respond to this change in grain by increasing territory size (in order to keep the amount of suitable structural habitat relatively constant) then their habitat selection will not appear to be as specific as on mountains. Two types of data are needed to test this hypothesis: first, it will be necessary to document that habitat types are more patchily distributed in this locale than on mountains, and second, to es-

Table 7.--Classification of Cranberry Lake observation vectors by Mountain Mansfield classification functions.

		Predicted Group Membership				
Actual Group	N	Wood thrush	Veery	Hermit thrush	Swainson's thrush	Gray-cheeked thrush
W.T.	13	62% (8)	23% (3)	15% (2)	0% (0)	0% (0)
Vy.	13	8% (1)	54% (7)	31% (4)	8% (1)	0% (0)
H.T.	13	23% (3)	15% (2)	46% (6)	15% (2)	0% (0)
S.T.	17	59% (10)	12% (2)	18% (3)	12% (2)	0% (0)

tablish a relative increase in territory size from montane to non-montane areas. Data of this sort will be collected over the next few breeding seasons.

The second hypothesis concerns historical factors. The geographical range of the Wood thrush has dramatically expanded over a short period of time. Only since 1890 has this species become a regular component of the breeding avifauna in the northeastern United States and Canada (Bent, 1949). Evidence supplied by Morse (1971), from an area in northern Maine recently invaded by the Wood thrush, indicated that the thrushes may be interspecifically territorial. In those aggressive encounters reported, the Wood thrush was behaviorally dominant and may have preempted territories previously occupied by other thrush species. However, in areas studied by Dilger (1956) and Noon (1977), where the Wood thrush was not a recent invader, there was no evidence of interspecific territoriality. In the Cranberry Lake region the Wood thrush may be a recent addition to the breeding avifauna (Adams, 1923) and its abundance is still substantially lower than any of the other thrushes. Because covert competitive interactions contribute strongly to these species' patterns of specific habitat selection (Noon, 1977), the Cranberry Lake region may not have reached a competitive equilibrium. Non-equilibrium patterns of resource utilization may be sufficient to explain the observed degree of habitat misclassification (though not the specific pattern of misclassification).

To summarize, tests in other locales of the habitat selection model developed from an extensive multivariate study of the breeding habitats of the northeastern montane thrush guild have indicated a lack of generality. In southeast mountains where two of the five guild members remain, habitat niche shifts have occurred as the result of changes in their competitive environment (Noon, 1977). In non-montane, but adjacent, areas in the northeast shifts in habitat utilization for some species are hypothesized to be the result of vegetational and historical factors. The implications are, at least for some forest birds, that habitat management schemes will have to be tailored to local conditions.

DISCUSSION

Habitat selection in passerine birds appears to be influenced by the physical structure of the vegetation without particular regard to the plant species present. In a variety of multivariate studies of avian habitats differences in a few structural variables were sufficient to significantly discriminate even very diverse communities (Whitmore, 1977). This consistency argues for some overriding patterns of community organization. Comparisons of community-level patterns of organization for northeastern and southeastern elevational gradients have been presented. In general, the patterns of organization for these communities are quite similar, but with noteable exceptions. The similarity of organization may most likely be a consequence of the migratory nature of the majority of breeders on these gradients.

Perhaps the most striking feature that emerged from the comparison of community structure on elevational gradients in the northern and southern Appalachian Mountains is their strong similarity. In terms of species richness, whether viewed over the entire gradient or on a station by station basis, the two gradients were virtually identical although there were many differenced in species composition. Rabenold (1976) compared the breeding birds of spruce-fir forests in Maine and North Carolina and concluded that the southern fauna was a depauperate subset of the northern. We did not find such a striking

difference and Rabenold's species list suggests that the Maine site may have contained greater horizontal heterogeneity. This coupled with the presence of spruce budworm specialists can account for at least part of the difference. Based on our data, the montane avifauna of the southeast does not follow the general trend of lower species richness southward discussed by Tramer (1974).

The communities were also quite similar with respect to the absence of obvious competitive exclusion patterns, the effect of ecotones on species turnover patterns (though somewhat reduced in the Smoky Mountains), and the pattern of species amplitudes on the gradients. These similarities imply that there is some generality to certain structural features of predominantly migratory temperate forest bird communities. In some of these same ways, both communities are quite different from tropical forest ones as discussed previously (Able and Noon, 1976). Most notably, the apparent absence of altitudinal segregation of putative competitors suggesting interference competition, and the large changes in community composition coincident of ecotones are in sharp contrast to the patterns described by Terborgh (1971), Terborgh and Weske (1975) and Diamond (1973) in two widely separated tropical areas.

In many ways the differences between the communities of the two areas are more interesting than their similarities. Whereas species richness was very similar, the communities in the Smoky Mountains were more extensively dominated by one or a very few species. This difference was not accomplished at the expense of the abundance of the rarer species. In fact, abundances of most species averaged higher in the Smoky Mountains than on the northern gradients and this difference was merely greater in the dominants. Rabenold's (1976) data reveal the same difference which he attributed to duced competition in the depauperate southern fauna. Our data don't admit this explanation, but there are other possibilities, none of which are yet tested. The breeding season is elongated in the southern mountains, allowing more double-broadedness and at least the potential of staggering breeding and thereby reducing competition. Differences in resource abundance, variety or temporal availability between the two regions could also effect changes in the competitive regime.

If competition across the community is relaxed in the southern mountains (and we do not assert that this is generally so), both the higher abundances of species and the smaller turnover of species at ecotones could be explained. Distributional boundaries coincident with ecotones are likely a product of habitat selection evolved and reinforced by competitive pressure. If ecotones were less sharp in the Smoky Mountains our results with regard to distributional limits would be explained. However, we have no evidence that this was the case. In addition, it must be emphasized that whereas a smaller proportion of species limits occurred at ecotones than in the Northeast, large changes in the relative abundance of species were still obvious.

If we examine the species which are dominants at various elevations on the Smoky Mountain gradient a common characteristic emerges. The most abundant species are also those that occupy the greatest elevational ranges on the gradient. The list of these abundant and broadly distributed species includes both migrants and residents, low- and high-elevation species, representatives of at least five families, and a variety of trophic specializations. The only feature they appear to have in common is that they are habitat generalists.

This relationship between "niche" width and abundance has been found in several kinds of communities, including birds (McNaughton and Wolf, 1970; but cf. Ricklefs, 1972). The causal factors in this relationship are by no means clear although it seems reasonable that species with broad habitat tolerances could reach and maintain larger local populations.

A final major difference between the communities on the two gradients is the ratio of migrants to regional residents. Superficially, the Smoky Mountain avifauna is more similar to a tropical one. However, many of the individuals of these species move at least to lower elevations in winter and those that do not apparently wander extensively (Stupka, 1963). Thus they are not sedentary in the sense that many tropical species are thought to be (e.g., Diamond, 1973; but cf. Karr, 1976, and references cited therein). Because in both areas virtually all individuals occupy their breeding territories for only a small fraction of the year, interspecific territoriality leading to the repulsion interactions described by Diamond (1973) and Terborgh (1971) may be impractical. As we argued previously, competitive pressures in these migratory temperate communities seem to have been resolved primarily through differential habitat selection. Under these conditions overt evidence of competition may be leacking as shown theoretically by Rosenzweig (MS), and empirically by Noon (1977).

Differences in community-level patterns reflect differences in population-level responses. Even if these distinctions are slight they may have important consequences for effective habitat management. If southeastern species are more generalized than their northeastern counterparts then they should be less adversely affected by specific changes in habi-

tat structure. On the otherhand, if southeastern species diversity is limited by peak resource abundance then attempts to increase local diversity by increasing local habitat heterogeneity will have only limited success.

Variability in a species' habitat selection may imply behavioral plasticity in response to proximate cues used to assess habitat suitability. Specificity of habitat selection in any one locale may by in response to interspecific competition (Noon, 1977) or simply to a lack of alternative suitable habitat. Effective habitat management for a specific species will depend upon accurately ascertaining these subtle influences. Managing structural habitat components to positively influence a particular species will most likely have negative influences on other species. The challenge for the habitat manager is to minimize these negative repurcussions.

Present land-use practices often result in the generation of small blocks of forest. The dramatic consequences of this forest fragmentation on avian communities has recently been reported (Whitcomb, 1977). Although these fragments contain patches of habitat structurally appropriate for certain species, those species are absent. Invariably these species are neotropical migrants which appear to be extremely size-sensitive. Proper management to insure the presence of these species means not only insuring appropriate habitats but that these habitats be contained within large tracts of continuous forest.

The analysis of the thrush habitat selection patterns have demonstrated the use of a multivariate analysis technique and its potential application to habitat management schemes. For example, using the results of discriminant function analysis a given location within a forest could be measured using the same subset of variables as were used in the habitat niche descriptions of the thrushes. Subsequent to plotting this point in discriminant space the location could be assessed according to its probability of containing a particular thrush species. If the forest site were not contained within the probability ellipse of the desired species, or if it would not support the theoretical maximum species complement, then, in theory, the habitat could be altered to include this (and other) species. An area with high structural diversity should generate a point in discriminant space that would simultaneously be contained within the probability ellipses of several species.

The consequences of habitat perturbations or successional changes would be reflected by movement of a forest's mean habitat vector in discriminant function space. Any habitat alteration which would move the mean vector closer to a species' centroid should be beneficial to that species since the population would have more suitable habitat available (Anderson and Shugart, 1974). Conversely, movement away from a species' centroid should have a negative effect on its population size and if moved sufficiently could cause local extinction.

The accuracy with which predictions of population change can be made depends upon the regularity of a species' habitat selection pattern independent of changes in its competitive environment. The more invariant a species' habitat selection the more accurately its population dynamics can be modeled. The results presented above represented a test of the generality of habitat selection of the northeastern montane thrush guild. They indicate that subtle changes in a species environment may generate substantial niche shifts. The successful management of avian wildlife will require a detailed understanding of the species' habitat requirements as well as the dynamics of its interactions with the rest of the community. Our data indicate that changes in community-level attributes may generate significant changes in a species' habitat utilization.

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Specialized Bird Habitats and Management

Moderator: J. W. Hardy
Florida State Museum

Snag Management for Cavity Nesting Birds

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Abstract.--Availability of snags on forest lands affects abundance, diversity, and species richness of cavity nesting birds. The effect of timber rotations, harvesting techniques, and fungal heart rots on nest site availability is examined. Research needs are surveyed and management recommendations suggested.

INTRODUCTION

Increases in availability of snags on forest lands have been shown to increase the abundance, diversity, and species richness of cavity nesting birds (Balda 1975b). If forest management is to favor these species and the production of snags as suitable nest sites, it must consider length of timber rotation, harvest techniques, fungal heart rots, and bird species.

This paper examines interactions that affect production of suitable nest sites and offers management recommendations that could increase snag availability.

SNAGS AND SNAG USE

In this paper, a snag will be defined as any dead, dying, or living tree suitable as a nest site for a cavity nesting bird. Snags are produced naturally by a variety of environmental factors, all of which stress and kill living trees. Fire, tree disease, lightning, flooding, and drought are some of the more obvious forces that stress trees (Keen 1955).

Birds use snags for a variety of purposes. Woodpeckers, chickadees, nuthatches, and brown creepers (*Certhia familiaris*) commonly use snags as foraging substrate. Flycatchers, shrikes, red-headed woodpeckers (*Melanerpes erythrocephalus*), bluebirds, and hawks regularly use open-area snags as perches to watch for prey. Many species of passerine birds that occupy edge or open habitats use snags as singing perches for territorial advertisement. Woodpeckers often use resonant undecayed portions of snags as drumming sites for territorial announcements.

Primary cavity nesters, such as woodpeckers, typically excavate their own nest and roost cavities in snags. Secondary cavity nesters use natural cavities and abandoned woodpecker excavations (Table 1). For example, owls often use woodpecker cavities as daytime roost sites, occasionally before they are vacated by woodpeckers (Conner 1973). Therefore, factors that cause trees to become suitable, potential nest sites for primary cavity nesters are the most important management parameters in snag production.

Natural cavities and woodpecker excavations are also used by animals other than birds (Gysel 1961, Kilham 1968, Dennis 1971, Erskine and McClaren 1972). Squirrels, mice, wood rats, bats, raccoons (*Procyon lotor*), and opossum (*Didelphis virginianus*) use cavities for winter and summer dens. Less noticeable residents are various species of funnel-web spiders, skinks, and tree frogs. Cavities provide dry shelters for these small predators as they wait for insects (Conner 1974).

SUITABILITY OF SNAGS AS NEST SITES

Recent studies demonstrate that even primary cavity nesters cannot nest in just any tree. These birds largely depend upon trees infected by fungal heart rots; such trees have softened heartwood that makes it easier for the birds to excavate a cavity (Odum 1941a and b, Steirly 1957, Shigo and Kilham 1968, Dennis 1969, Ligon 1970, Kilham 1971, Conner et al. 1975, Crockett and Hadow 1975, Conner et al. 1976, Jackson 1977b).

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able 1.--Selected list of cavity nesting birds (Robbins et al. 1966, Dennis 1971, Erskine and McLaren 1972, Mowbray and Goertz 1972).

Species	Primary or secondary cavity nester	Specific references on nesting sites
ood Duck (*Aix sponsa*)	secondary	Bent 1923, Bellrose et al. 1964.
merican Kestrel (*Falco sparverius*)	secondary	Bent 1938
creech Owl (*Otus asio*)	secondary	Bent 1938
ommon Flicker (*Colaptes auratus*)	primary	Burns 1900, Bent 1939, Conner et al. 1975, Conner et al. 1976, Conner and Adkisson 1977.
ileated Woodpecker (*Dryocopus pileatus*)	primary	Bent 1939, Hoyt 1957, Conway 1957, Jackman 1974, Conner et al. 1976, Conner and Adkisson 1977, Bull and Meslow 1977.
ed-bellied Woodpecker (*Melanerpes carolinus*)	primary	Bent 1939, Reller 1972, Jackson 1976.
ed-headed Woodpecker (*Melanerpes erythrocephalus*)	primary	Bent 1939, Reller 1972, Conner 1976, Jackson 1976, Conner and Adkisson 1977.
ellow-bellied Sapsucker (*Sphyrapicus varius*)	primary	Bent 1939, Kilham 1971.
airy Woodpecker (*Picoides villosus*)	primary	Bent 1939, Lawrence 1966, Kilham 1968, Conner et al. 1975, Conner et al. 1976, Conner and Adkisson 1976, 1977.
owny Woodpecker (*Picoides pubescens*)	primary	Bent 1939, Lawrence 1966, Conner et al. 1975, Conner et al. 1976, Conner and Adkisson 1976, 1977.
ed-cockaded Woodpecker (*Picoides borealis*)	primary	Bent 1939, Steirly 1957, Ligon 1970, Thompson (ed.) 1971, Jackson 1977a and b, Kilham 1977.
reat Crested Flycatcher (*Myiarchus crinitus*)	secondary	Bent 1942.
ree Swallow (*Iridoprocne bicolor*)	secondary	Bent 1942.
lack-capped and Carolina Chicakdees (*Parus atricapillus* and *P. carolinensis*)	both	Bent 1946, Odum 1941a and b.
ufted Titmouse (*Parus bicolor*)	both	Bent 1946.
hite-breasted, Red-breasted, and Brown-headed Nuthatches (*Sitta carolinensis*, *S. canadensis*, and *S. pusilla*)	both	Bent 1948.
rown Creeper (*Certhia familiaris*)	secondary	Bent 1948.

Table 1.--Continued

Species	Primary or secondary cavity nester	Specific references on nesting sites
Carolina Wren (*Troglodytes ludovicianus*)	secondary	Bent 1948.
Eastern Bluebird (*Sialia sialis*)	secondary	Bent 1948, Conner and Adkisson 1974a, Pinkowski, 1976.

Many of these studies also suggest that woodpeckers can excavate nest cavities in non-infected trees. In such studies, however, the presence of fungal fruiting bodies on tree exteriors was relied on to indicate heart rot. But species of fungi that cause primary infection of heart rots do not typically fruit on the exterior of nest trees, and in many cases there is no other sign of decay on the outside of a nest tree with heart rot (Conner et al. 1976). In such cases, aseptically removed chips of heartwood from the tree core near the nest cavity should be cultured in the laboratory to check for fungi.

SEQUENCE OF HEART ROT INVASIONS

Heart rot fungi commonly enter through dead branch stubs (Hepting and Chapman 1938, Baumgartner 1939, Conner et al. 1976), but can also enter through tree bark damage. Wind-blown spores then come in contact with favorable growing conditions (Shigo and Larson 1969).

Once a fungus has entered a tree it usually decays a small area and then spreads throughout the heartwood. Woodpeckers apparently detect heart rot by pecking the tree and distinguishing a particular resonance (Conner et al. 1976).

Woodpeckers often start cavities but may abandon an excavation site when sound, undecayed heartwood is encountered (Conner et al. 1976, E. L. Bull pers. comm.). Jackson (1977b) has suggested that red-cockaded woodpeckers (*Picoides borealis*) excavate nest cavities slowly in areas where suitable potential nest trees are lacking. The woodpeckers can only excavate until they reach sound heartwood and must wait for fungal activity to decay wood tissue. In such cases, excavation may take more than a year.

IDENTIFICATION OF POTENTIAL NEST TREES

Potential nest trees for primary cavity nesters are those infected with "top rots," heart rot fungi that invade the trunk or main limbs in upper regions of the tree. If a tree is to be classified as a suitable, potential nest tree, heart rot must be detected at the range of heights and stem diameters where woodpeckers normally nest (Table 2). Possible existence of suitable nest site conditions could be detected by observing:

1. Fungal conks (fruiting bodies) of species known to cause heart rots (Shigo and Larson 1969, Hepting 1971, Miller 1972, Conner et al. 1976).
2. Dead branch stubs (Shigo and Larson 1969, Baumgartner 1939, Conner et al. 1976).
3. Old wounds or scars on trees resulting from mechanical, lightning, or fire damage (Hepting 1935, Hepting and Hedgcock 1937, Stickel 1940, Toole 1959, Shigo and Larson 1969). With sufficient time butt rots will grow high enough in the heartwood of trees to create suitable nest site conditions (Toole 1959).
4. Discolored or soft, decayed wood in increment borer corings (Toole 1959, Shigo and Larson 1969, Conner et al. 1976, Jackson 1977b).
5. Existing woodpecker holes or cavities.
6. Obvious dead portions of trees.
7. Testing the tree with a "Shigometer" --Northeastern Forest Experiment Station--photo story No. 29, Upper Darby, Pa. 19082.

Table 2.--Nest site characteristics of several primary cavity nesters. Values presented are a subjective estimate of optimal conditions based on data in the literature (see individual species list, Table 1). CAUTION--These values will vary for tree species and geographical areas different from those where initial data were collected.

Species	Nest cavity height (m)	Tree diameter at nest (cm)	Preference for live or dead section of trees[1]	DBH of nest tree (cm)	Age of nest tree (yrs.)
Red-cockaded Woodpecker	3-12	unavail. in lit.	live	26-60	70-100
Downy Woodpecker	2-11	15-30	dead (both)	17-60	60-70
Hairy Woodpecker	3-17	20-40	both	22-60	85-95
Red-bellied Woodpecker	3-18	15-35	dead (both)	30-76[2]	60-200[2]
Red-headed Woodpecker	4-20	24-36	dead (both)	70-110[3]	140-300[3]
Common Flicker	3-18	26-60	dead (both)	30-120	60-300
Pileated Woodpecker	5-17	30-45	both	35-85	100-180
Black-capped Chickadee	2-9	9-15	dead	unavail. in lit.	unavail. in lit.

[1] - This parameter shows extreme geographic variation.

[2] - Conner, unpublished data in oak-hickory timber type (n = 4)

[3] - Based on mature oak-hickory wood lots--values probably less in southern pine types.

8. Identification of fungi from culture of wood obtained by coring trees with an increment borer (Davidson et al. 1942, Nobles 1965, Conner et al. 1976.

Conks on the outside of a tree do not always indicate a heart rot, and thus a potential nest tree. Sap rots which infect and kill living xylem and phloem tissue also produce conks. The condition of the sapwood, however, may influence suitability of trees as nest cavity sites for certain species. Downy woodpeckers (*Picoides pubescens*) and common flickers (*Colaptes auratus*) in eastern U.S. rarely excavate nest cavities in oaks (*Quercus* spp.) and hickories (*Carya* spp.) with a living cambium at the nest areas. Eastern pileated (*Dryocopus pileatus*) and hairy (*Picoides villosus*) woodpeckers often excavate through a living hardwood cambium to reach a decayed heartwood core (Conner et al. 1975). Downies and flickers apparently need sap rots to soften outer portions of trees as well as heart rots when hardwoods and possibly pines (*Pinus* spp.) are used.

EFFECTS OF TIMBER MANAGEMENT ON NEST TREE PRODUCTION

Rotation time, or time between clear-cutting, affects nest tree production. At present, rotation times are often established to maximize timber production and minimize loss of products to decay and similar factors (Hepting 1971). Short rotation times that maximize timber production may reduce the chance of trees growing large enough to house nest cavities (Table 2). Sufficient time must also pass to allow fungal heart rots to adequately decay trees. However, there is no information available to define the time needed for various heart rot fungi to decay trees to the extent required for nest excavation.

Based on U.S. Forest Service guidelines (Forest Service Manual, Section 24-10, and 24-15) rotation times for pines on National forest lands in southern forests are about 65 to 70 years. At that age stands range from 40 to 55 cm dbh depending on site condition and can be used for pulpwood and/or sawtimber. When this dbh range is compared with trees selected as nest sites by the seven woodpecker species, the Forest Service

rotation scheme falls within the dbh ranges used (Table 2). Nest trees are apparently being produced. However, only the downy, red-bellied, and flicker nest regularly in trees younger than 65 to 70 years. This suggests that more time is needed for trees to become suitably infected with fungi.

A study of Fomes pini in southern pines demonstrates an increase in fungal activity with age (Hepting and Chapman 1938). Only one out of 40 trees was sufficiently infected with rot to be culled after 80 years, ten years beyond the Forest Service rotation for southern pines. Forest Service rotation on bottomland hardwoods is 100 years, perhaps a bit more favorable for cavity nesters.

Rotations practiced by private paper companies are shorter than those set by the Forest Service. Where southern pines are managed for pulpwood production, rotations of 20 to 30 years are preferred (Johnson in Slusher and Hinckley 1974). If both pulpwood and sawlogs are desired, rotations are 35 to 40 years.

Timber harvest techniques also influence cavity nesters. In the National Forests of southwestern Virginia, snags and nest trees were left standing during clearcutting operations and a variety of wildlife used these trees: bluebirds (Conner and Adkisson 1974a), woodpeckers (Conner and Crawford 1974, Conner et al. 1975), and red-tailed hawks (Buteo jamaicensis) (Conner and Adkisson 1974b). Ages of these stands when clearcut ranged between 100 and 150 years (Conner unpublished data), apparently a sufficient time for fungi to create suitable nest sites. However, snags are highly susceptible to fire and have the potential to fall; they are therefore considered undesirable by many forest managers (McClelland and Frissell 1975).

Firewood collections on national forests remove many snags. The Forest Service occasionally opens up sections of land so that the public can pick up or cut any dead or fallen trees at no cost. In areas where nest sites are limited, such practices should be discontinued if cavity nesters are to be favored.

CALCULATIONS OF MINIMAL SNAG DENSITY

Several formulas have been devised to calculate the minimum snag density needed by a cavity nesting species. Based on data collected in Arizona, Balda (1975a) calculated the number of snags needed to support secondary cavity nesters in ponderosa pine (Pinus ponderosa) forests. The Forest Service has developed guidelines for additional formulas (Bull and Meslow 1977). Factors used in the calculations include: (A) maximum bird species density in pairs per square mile, (B) number of snags used annually for nesting and roosting, and (C) a reserve of snags: 15 for each one used. These three figures are then multiplied times each other ($A \times B \times C = Y$), where Y equals the number of suitably sized snags required per square mile by the species.

If the timber on an area is to be cut, the number of snags to be left can be calculated with the following formula (Bull and Meslow 1977): $S = T(L-R) + Y$

Where S = number of snags to be left per square mile
T = years to next harvest
L = annual snag loss per square mile
R = annual snag recruitment per square mile
Y = number of suitably sized snags required.

Snags fall, and a sufficient number should be left to insure an adequate supply for cavity nesters until replacements become available. When leaving snags it is best to choose those that will last the longest (McClelland and Frissell 1975) as well as those with cavities that are of immediate use. It should also be noted that snags in clearcuts benefit species that select open environments but do not favor cavity nesters that require deep woods habitat.

ARTIFICIAL PRODUCTION OF NEST TREES AND SNAGS

Nest trees and snags could perhaps be created artificially during timber harvest operations and in uncut forest stands. Silvicide injections are often used to kill unwanted trees during clearcutting to eliminate competition for light, moisture, and nutrients.

Research is needed to determine if heart rot fungi are inhibited by the silvicides. The effect of silvicides on insect invasions as well as toxicity to wildlife (e.g. dioxin in 2,4,5-t) also needs to be examined since snags are regularly used as foraging sites. Several studies have already shown that certain herbicides have a toxic and teratological effect on insects, wildlife, and the ecosystem (Orians and Pfeiffer 1970, Galston 1971, President's Scientific Advisory Comm. 1971, Westing 1971, Moffett et al. 1972, Morton et al. 1972, Lichtenstein et al. 1973, Wilson 1973, Kenaga 1974).

If silvicides do not prevent production of suitable, potential nest sites and do not harm wildlife, injections might be made in uncut stands and during lumbering operations to increase snag density.

Frill girdling of trees and inoculation with sap rots may be an alternative method of eliminating unwanted trees and making nest sites.

Artificial nest sites might be produced even more rapidly through a technique suggested by Affeltranger (in Thompson (ed.) 1971). Trees could be bored and possibly inoculated with an appropriate species of fungus at heights and positions where woodpeckers normally excavate nest cavities (Table 2). Consideration must be given to the orientation of woodpecker nest entrances (Burns 1900; Bent 1939; Lawrence 1966; Dennis 1969, 1971; Baker in Thompson (ed.) 1971; Kilham 1971; Reller 1972; Conner 1975; Inouye 1976; Conner 1977). Bore holes should be placed on the underside of leaning trees so that the openings point 10 degrees below the horizontal (Conner 1975). The preference of individual woodpecker species for either live or dead sections of trees as nest sites must also be considered (Table 2).

The general habitat requirements of cavity nesters should be considered when artificially creating nest trees. Treated trees should be located in habitats with basal areas, vegetation densities and heights, etc., that are acceptable for a particular cavity nester (See references in Table 1).

MANAGEMENT RECOMMENDATIONS

If forest management is to favor nest sites for cavity nesters, the following recommendations can be employed:

1. If timber on an area is to be harvested, increase silvicultural rotation times to a minimum of 100 years for most cavity nesters, and to 150 years for the pileated woodpecker (benefits forest cavity nesters). (Note--total habitat requirements of individual species must also be considered.)

2. When harvesting timber leave a sufficient number of suitable snags for present and future use by cavity nesters (See Bull and Meslow 1977) (optimizes open area cavity nesters).

3. If timber is not to be harvested, manage the area as wilderness (optimizes mature forest cavity nesters).

4. Discontinue removal of dead, dying, and decayed trees for use as materials or firewood in areas where nest cavity sites are limited.

5. Create suitable nest sites by frill girdling trees and inoculating them with sap rots.

6. Pending results from further research, bore holes in suitably sized trees and inoculate with a suitable heart rot fungus. (Local bird clubs could help in this management practice.)

7. When managing for individual species, be aware of specific nesting habitat (basal area, vegetation density, etc.) and nest tree requirements, i.e., living, dead, top broken off, etc. (See references for individual cavity nesting species, Table 1).

RESEARCH NEEDED

Further research is needed on the following subjects before snag management for cavity nesters can be optimized:

1. Determine the fungi species responsible for producing suitably decayed nest trees in southern forests.

2. Investigate the utility of silvicide injection and frill girdling as methods of producing suitably decayed trees for cavity nesters. The effect of silvicides on fungal heart rots, insects, wildlife, and the ecosystem must be determined.

3. Determine the time period necessary for each particular sap and heart rot species to invade and suitably infect different tree species. (See Toole (1959), butt rot invasion sequence versus time.)

4. Determine the effectiveness of bore holes and subsequent inoculations with an appropriate fungi species for artificially creating suitable nest trees.

5. Determine how long snags of various tree species will remain standing.

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Raptor Management[1]

Malcolm G. Edwards[2]

Abstract.--Interest in raptors and their preservation has resulted in state and federal laws protecting them from trapping, shooting and poisoning. While many of man's activities are destructive, some can be modified to lessen their impact on raptors.

INTRODUCTION

Until recent times, the white man has considered all raptors vermin and they were shot, trapped and poisoned. This persecution resulted from competition with man for prey species and from occasional forays into domestic birds and animals. As more information on the predator-prey relationship was disseminated, the farmer and the hunter slowly changed. The crash in the population of many hawks due to the widespread use of toxic insecticides in the 40's and 50's attracted the attention of bird fanciers, biologists and other groups. Consequently, state and federal laws were passed protecting raptors.

The goal of raptor management is difficult to define. It has been characterized as having three points of view: economic, recreational and scientific (Snyder 1975). In the Southeast, most poultry is raised under cover and direct losses to farmers are slight. Commercial shooting preserves, however, may have serious problems with individual red-tails and Cooper's hawks. Most important are the economics of preserving habitat threatened by developers. Recreation needs vary, with nature enthusiasts wanting many species in a natural setting while falconers are primarily interested in the larger accipiters, buteos and falcons.

With a few exceptions, management has consisted mostly of protection from shooting, disturbance and poisons. In many cases this protection is sufficient to sustain a viable population. More comprehensive management strategies have been developed for the bald eagle (Mathieson et. al. 1977) and the peregrine falcon (Cade 1975a). A proposal for saving an endangered or threatened population has been developed (Olendorff and Stoddart 1974).

The management of raptors sometimes seems futile due to their mobility. If conditions are unsuitable in one place, they simply move until they find what they need. However, manipulation of habitat, urban growth and other activities of man have reduced the total habitat. The more adaptable red-tailed hawk has not been affected as much as the less adaptable bald eagle. The bird hawks (peregrine falcon, Cooper's and sharp-shin hawk) have suffered heavy losses due to the ingestion of toxic chemicals.

MAN'S IMPACT ON RAPTORS

Some species of raptor is found in almost all situations, including the center of large cities. The impact of man's activities on raptors results from--

--timber management

--shooting

--pollution of water, damming, channelization

--urban sprawl

--pesticides

--falconry

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Timber Management

Timber management may damage or enhance habitat, depending on the type of cut and the raptor. A newly cut timber stand is rich in passerines (Hooper 1967) and small mammals and attracts the accipiters and buteos. However, most buteos and owls need large, mature trees for nesting and perching. Screech owls and kestrels nest in tree hollows, usually found in mature or overmature timber. A number of safeguards can be built into timber sale operations to protect raptors and maintain suitable habitat.

When a stand of timber is regenerated or has an intermediate cut, all known active hawk and owl nests should be tied into a special zone such as a water influence zone or into a clump of trees being retained for future den trees. If any of the historical peregrine falcon eyries become active, timber operations should be stopped within 1/2 mile of the base of the cliff during the nesting period of March 1 through June 30. Special considerations are unnecessary when eyries are inactive. To encourage raptors, at least one perch tree for hunting should be retained in each 5 acres of cutover area. Preferably this will be a den tree. In stands where prescribed burning may be practiced, a large healthy pine should be retained. With most agencies and many commercial timber managers, it is customary to leave strips of trees along streams and lakes. The larger trees in these strips are important for eagle and osprey nesting. As large dens develop slowly and are critical to some of the owls, all den trees with an opening of 5" or over should be retained, regardless of location.

A balance of age classes and timber types with good dispersion of both will provide habitat for many raptors. Pure stands of pine provide very little for raptors so both upland hardwoods and bottomland hardwood stringers are needed. An exception is newly thinned and burned pine stands which are known to be used by golden eagles. In site preparation prior to seeding or planting, den and perch trees, buffer zones and other key areas must be protected. In planted pine stands, wider planting intervals are preferred because the grass and forbs growing between rows provide better habitat for small mammals.

Bald eagle nesting sites require protection. In the absence of a survey of territory size, a tentative area of 120 acres has been assumed on Southern Forests (U. S. Forest Service 1974). Within this zone, land use practices that alter habitat are prohibited. Disturbance will be held to the present level or reduced. Any cutting will be by the selection method. Activities such as timber harvesting, cultural improvements and road construction will not be conducted within one-half mile of nests during the time of egg laying, incubation and the first month after hatching (Chamberlain 1974).

Shooting

While most raptors are protected by both state and federal law, many are still crippled and killed by gunshots each year. The Eagle Rehabilitation Center at Auburn University received 5 crippled eagles in 1977. Generally crippled birds are picked up by state or federal law-enforcement personnel and taken to a veterinarian or falconer who is interested and has a permit for rehabilitation. No one knows how many are shot and left. There is no question though, that shooting is on the decline due to law enforcement and education.

There are many individuals, including veterinarians, who are interested in rehabilitating raptors. In some cases, the bird can be returned to the wild. Disposition of the others which are permanently crippled from gunshot wounds is a problem. Most zoos and museums have all they want and some of these volunteers find themselves keeping 5 or 6 hawks and owls on a permanent basis. Euthanasia is the only practical solution but is very distasteful. Rehabilitating the more common hawks and owls is not really practical, but human nature being what it is, these efforts will continue.

Water Pollution and Channelization

Water pollution, channelization and dredging affects both eagles and ospreys by reducing the supply of fish. Studies have shown a reduction of 68% of the fish population in channelized streams (Tarplee, Louder, Weber 1971). Investigations have also shown that fish from polluted waters introduce toxic chemicals into these birds (Anonymous 1970). Dredging and thermal pollution also have far reaching effects in reducing the fish population (Smith 1971). Manmade reservoirs, however, may contribute to the habitat of ospreys and eagles.

Urban Sprawl

The preemption of forests and fields for factories and subdivisions has caused problems for many raptors as it reduces their total habitat. On the other hand, the interstate system that has accompanied

this development has improved conditions for the red-tailed hawk. The seeded cuts and fills are prime habitat for cotton rats and other small mammals and few people will shoot from or across an interstate. Here in Georgia, a wintering red-tail for each linear mile of interstate has been noted often. Conversely, screech and barred owls seem particularly susceptible to being struck by automobiles.

Pesticides

There has been so much written about the effects of the toxic chemicals on raptors that this paper will not discuss this in detail. Although DDT is no longer used in this country, it is still a threat as it is widely used in South America and wintering raptors ingest these poisons with their prey (Lincer, Sherburne 1974). A further threat is the return to North America of prey species which carry heavy concentrations of these dangerous chemicals. However, the problem doesn't seem as serious as it was when these poisons were used in the Continental United States. The number of immature arctic peregrine falcons seen and banded has remained static for the last 5 years, indicating good reproduction.

Falconry

The number of raptors taken by falconers is insignificant. The birds kept are marked and replacements are closely monitored. To illustrate the extent of falconry in the Southeast, South Carolina has 3 registered falconers, Georgia has 12, Alabama has 3, and the practice is illegal in North Carolina. No falconer is permitted to keep more than 3 birds and only immature birds may be trapped. There is much interest in captive breeding of hawks and falcons for use by falconers. The drain on wild birds is quite small.

ENDANGERED SPECIES

Endangered raptors in the Southeast are the southern bald eagle and the eastern and arctic peregrine falcons. Other than captive birds in breeding projects, the eastern peregrine is apparently no longer present as a breeding population. The arctic peregrine is observed in large numbers in its fall migration down the Atlantic coast and in lesser numbers throughout the East. A breeding bird census of ospreys and bald eagles taken annually on Southern National Forests and adjoining lands shows an increase in number of nests and number of young birds fledged since 1972.

DIRECT HABITAT IMPROVEMENT

Little has been done in the Southeast that can be defined as a direct habitat improvement. For many years there has been a wintering population of 4 to 6 golden eagles in the high plateau along the Blue Ridge Parkway on the Pisgah National Forest in North Carolina. The area is open country with scattered shrubs and trees and abundant cottontail rabbits and other small mammals. Each year a part of this land is burned to retain the old-field stage of succession. This both perpetuates the large mammal population and keeps it open enough for eagles to maneuver.

Studies are also being made on the practicality of creating tree dens in pole size timber with the use of a power drill. The premise is that dens started in young trees will be large enough for raptors and other den dwellers when the trees are 60 or 70 years of age. Natural large dens take much longer to develop. Artificial nest boxes have been successfully used by kestrels (Hammerstrom, Hammerstrom, Hart 1973) and screech owls. Plans exist for reestablishing peregrine falcons on historical eyries in the Southern Appalachians (Cade 1975a). Conceivably new artificial eyries may be created in suitable habitat where cliff faces do not provide natural ledges.

For several years, a pair of golden eagles has wintered on the Lake Burton Game Management Area on the Chattahoochee National Forest in North Georgia where they are sustained on the carcasses of deer killed illegally or accidentally and gathered by the Game and Fish Commission.

Artificial nest structures have been erected for osprey use but without success in North Carolina and Florida.

SUMMARY

Raptor management is new and few proven practices are known which result in increased populations.

Raptors have been impacted for many years by the activities of man resulting in death due to shooting, poisoning and reduction of habitat and prey base. Timber management decreases habitat for some raptors and creates it for others. Modifications of timber operations can lessen this impact. Shooting and

pesticides poisoning have decreased although too late for the eastern peregrine falcon. The banning of toxic pesticides, protection against shooting and education has resulted in stable and increasing populations of some raptors.

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COMMON SOUTHEASTERN RAPTORS

COMMON NAME	ZOOLOGICAL NAME	HABITAT[1/]
Arctic Peregrine Falcon	Falco peregrinus tundrius	Migrant and occasional winter resident along all coast
Barn Owl	Tyto alba pratincola	Fields and sparse woods
Barred Owl (Northern)	Strix varia varia	Oak-pine, oak-hickory, oak-gum-cypress, white-red-jack pine, maple-beech-birch
Barred Owl (Florida)	Strix varia alleni	Palmetto hammocks oak-gum-cypress
Black Vulture	Coragyps atratus	Not restricted to any timber type
Broadwinged Hawk	Buteo platypterus	Oak-hickory, oak-pine, oak-gum-cypress, maple-beech-birch
Burrowing Owl (Florida)	Speotyto cunicularia	Prairies of central and south Florida
Cooper's Hawk	Accipiter cooperi	Broken woodlands of oak-hickory, oak-pine, white-red-jack pine, maple-beech-birch
Everglade Kite	Rostrhamus sociabilis	Swamps and marshes of Florida
Golden Eagle	Aquila chrysaetos canadensis	Winter resident, may be found in all types
Great Horned Owl	Bubo virginianus	Oak-hickory, oak pine, oak-gum-cypress, maple-beech-birch, white-red-jack pine, spruce-fir
Marsh Hawk	Circus cyaneus hudsonia	Marshes, fields and meadows including coastal areas
Mississippi Kite	Ictinia misisippiensis	Open areas in lowlands, oak-gum-cypress, longleaf-slash pine
Osprey	Pandion haliaetus carolinesis	Around lakes and reservoirs throughout Southeast
Pigeon Hawk	Falco columbaris	Migrant and occasional winter resident throughout Southeast including coastal areas
Red-tailed Hawk	Buteo jamaicensis	Field borders, oak-hickory, oak-pine
Red-shouldered Hawk	Buteo lineatus	Oak-gum-cypress, Oak-hickory
Screech Owl (Eastern)	Otus asio	Fields and broken woodland oak-hickory, oak-pine, maple-beech-birch

Screech Owl (Florida)	Otus asio floridanus	Peninsular Florida, oak-hickory, oak-gum-cypress, longleaf-slash pine
Sharpshinned Hawk	Accipiter striatus	Broken woodland, oak-hickory, oak-pine, oak-gum-cypress, maple, beech-birch, spruce-fir
Shorteared Owl	Asio flammeus	Fields, meadows, cut over areas in winter
Sparrow Hawk	Flaco sparverius	Fields, meadows, coastal areas
Southern Bald Eagle	Haliaeetus leucocephalus	Coast and inland waters, nests in large pines
Swallow-tailed Kite	Elanoides forficatus	Marshes and swamps, oak-gum-cypress
Turkey Vulture	Cathartes aura	Not restricted to any timber type

1/Timber types from National Atlas, USGS, 1970.

Wading Birds and Wetlands Management

Mary C. Landin[1/]

Abstract.--Management of wetlands for wading birds is a little known research area. Prior research has primarily been directed toward estuarine and coastal areas. Freshwater wetlands in the Southern United States have declined dramatically in the past 150 years, as have populations of the bird species dependent upon those areas for habitat. Human recreational activities, fill and drain efforts, channelization, and dredging are primary causes of wetlands decline. Pesticides and poor water quality as well as the forementioned factors contributed to the decimation of bird populations. Habitat development and management practices would benefit all marsh users as well as the 27 species of wading bird species discussed. Five management techniques are set forth: (1) preservation and management of all existing wetlands; (2) creation of new wetlands areas; (3) expansion of some temporary wetlands to permanent areas; (4) maintenance of high water quality; (5) year-round protection of wetlands areas from humans and predators.

INTRODUCTION

Management of wetlands for wading birds is a little known research area which has historically not been given much consideration. This is especially true in freshwater wetlands, although research efforts have been made concerning protection and development of habitat in coastal areas by the U. S. Army Engineer Waterways Experiment Station (WES), the U. S. Fish and Wildlife Service (USFWS), the National Oceanic Atmospheric Administration (NOAA) through the Sea Grant Program, the National Park Service, the National Audubon Society, and to a limited degree, some state conservation agencies, and private citizens.

Past and present research by these agencies or groups have been tailored to meet the needs of each agency. The WES studies are nation-wide efforts to determine the extent of use (nesting, loafing/roosting, and feeding) of dredged material islands by colonial nesting sea and wading birds throughout the United States coastal, riverine and Great Lakes waterways. Their objective is the establishment of guidelines for management and development of these 2000+ Corps-made islands (Landin and Soots 1977).

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The USFWS Coastal Ecosystems Team is presently making a survey of Eastern and Gulf Coast colonies of wading birds with the intention of mapping these colony locations (Portnoy 1977, Custer, unpublished data). Their objective is to be better able to protect the colonies through their refuge systems, land aquisitions, and other means.

NOAA through Sea Grant has sponsored research at state levels. The most outstanding study in terms of wading bird habitat management was conducted by Soots and Parnell (1975) in the North Carolina estuaries.

State efforts have usually been in cooperation with state universities and have been more localized, site-intensive research (Williams and Martin 1968; Ryder 1977; John Smith 1976, Texas Parks and Wildlife, personal communication).

The National Park Service has funded research efforts of Buckley and Buckley (1976) which has resulted in a general guidelines manual for protection of existing sea and wading bird colonies on the East Coast.

The National Audubon Society established sanctuaries for wading and sea birds years ago in key locations. Most of their protected areas have been coastal (Mills 1934, Dunstan 1977) but a few sites are inland. These areas are generally only nesting/roosting sites

however, and can offer no protection from destruction of feeding habitat outside the sanctuaries. Only when colonies of wading birds are established in large refuges with accompanying wetlands to ensure feeding habitat are they a successful and continuing entity.

HISTORIC REVIEW

One hundred fifty years ago, before the intensive efforts to fill, drain, or dredge the wetlands and waterways, there existed in the interior Southeastern United States large expanses of freshwater swamps and marshes such as the Big Cypress and the Everglades in Florida; the Great Dismal Swamp of Viginia; Grand Bay, Okefenokee and Altamaha Swamps in Georgia; White River Bottoms, Swan Lake, and Slovac Thicket in Arkansas; I'On Swamp in South Carolina; Reelfoot Lake in Tennessee; and the Tensas Bottoms of Louisiana (Goodwin and Niering 1971, Niering 1966). These areas still exist today on a much reduced, altered scale. However, there had also been numerous other smaller wetlands scattered throughout the South that have totally disappeared through fill and drain efforts for farmland or city expansion.

These freshwater wetlands had supported a large and varied wildlife population, not the least of which were tremendous colonies of eleven species of herons, egrets, ibises, and cormorants that nested at Reelfoot Lake, Swan Lake, Okefenokee Swamp, the Everglades and other suitable areas (Audubon 1944, Bent 1926, Meanley 1972). In addition, they provided habitat for numerous song birds and solitary nesting marsh birds such as the bitterns, rails, American coots (Fulica americana), wood ducks (Aix sponsa), gallinules, limpkins (Aramus guarauna), sandhill cranes (Grus canadensis), and marsh wrens. They also provided resting and feeding areas for migratory ducks, geese, and swans, and 20 species of shorebirds as they moved between breeding and wintering grounds (Errington 1966, Niering 1966).

Since the 18th century man has ditched and attempted to drain wetlands, and since the 1930's has succeeded in draining for agricultural use in the South alone some 20-30 million hectares (Stransky and Halls 1967). Thousands of wetland hectares have been inundated by reservoirs. Along with the drastic diminishing of Southern wetlands, populations of marsh birds declined as well (Bent 1926, Meanley 1972). Some bird species whose ranges and occurrances were reported by Audubon (1944) and Bent (1926) are now listed as extinct or endangered throughout much of their former range and other species' ranges have been drastically reduced (Meanley 1972; USDI 1977).

Our present day Southern interior wetlands consist of isolated pockets of swamps and river bottoms that could not be drained for agriculture by ditching or stream channelization. Channelization was even more detrimental to wetlands than mere ditching (Wharton 1970) because the destruction and restructuring of a biotic community occurred when streams were straightened and cut clean of protective vegetation (Alexander 1963). If any thought to wildlife was given in prior channelization practices, it was to game fish populations. No consideration to water quality nor non-game wildlife was given and as Russell (1966) pointed out, wildlife is now suffering the consequences of this lack of thought. He suggests that laws be enacted requiring a 17-meter buffer zone between all streams and waterways and agricultural and forestry operations. This would provide for cleaner water, and more and better habitat for both fish and wildlife populations.

Dredging of waterways have had an effect on declines in inland wading bird populations by the increase in turbidity of water (USAEDSL 1975). Water turbidity and quality are key factors in declines, since wading birds are visual fish-eaters, and must be able to see their prey.

Another very important practice in the South is the heavy use of pesticides on agricultural crops. Residues from fields wash and leach into lakes, streams, and wetlands, and contaminate these areas. These areas have become sinks for these contaminants, unsafe for fishing, boating, and swimming; and in some areas these activities have been prohibited temporarily (the Mississippi Delta oxbow lakes are examples of this). The most visible evidence of problems with pesticide and fertilizer contamination is fish kills and depletion of game fish species. Less apparent but just as deadly is the biomagnification resulting from continued use by fish-eating birds of the contaminated fish sources. Numerous cases of population decline of bald eagles (Haliaeetus leucocephalus), ospreys (Pandion haliaetus), other raptors, and wading and sea birds have been noted by many authors due to eggshell thinning from contamination which results in unsuccessful nesting attempts. Indeed, even though its use has been banned for several years, the continued spector of DDT/DDE contamination haunts our Southland and other heavily agricultural areas.

Forest harvest practices in the past, although not having the wide-reaching effects of agronomic practices, have also played a role in wildlife population declines (Clawson 1975). Clear cutting, which allows greater erosion and stream pollution unless carefully managed, has

contributed to the problem. Stream bank cutting and ditching to drain hardwood bottomlands and bald cypress (Taxodium distichum) stands for forestry equipment access have changed stream temperatures, ground water levels, sediment and chemical loads in streams (Clawson 1975).

Urban and industrial development cannot escape blame in the decline in wading/marsh bird populations. As the human population has grown, pressures from industrial sites and their wastes, human recreation activities (boating, fishing, hunting, and even bird-watching), human housing needs, and other uses generally termed as "progressive" in our eyes, have all contributed to disruption of life cycles and destruction of habitat necessary for birds' survival.

HABITAT REQUIREMENTS

Life requirements of the six major bird groups using southern wetlands are quite different (Robbins et al. 1966). These six groups are: 1) migrating and overwintering shorebirds; 2) migrating and overwintering waterfowl, including the resident wood ducks and hooded mergansers (Lophodytes cucullatus); 3) the fish-eating raptors that generally overwinter, although some nesting still occurs; 4) the wetland nesting and feeding passerines, woodpeckers, and belted kingfishers (Megaceryle alcyon); 5) the solitary nesting rails, gallinules, coots, limpkins, sandhill cranes, and bitterns; and 6) the colonial nesting herons, egrets, ibises, and cormorants. For the purposes of this paper only Groups 5 and 6 which include 27 species (Table 1) will be considered and discussed, although in general any habitat preservation or development will help all wetlands users.

Table 1

Wading bird species that use freshwater wetlands for nesting and/or feeding and loafing.

Colonial Nesters

Great egret(Casmerodius albus)
Snowy egret(Leucophoyx thula)
Great blue heron(Ardea herodias)
Little blue heron(Florida caerulea)
Green heron(Butorides virescens)
Black-crowned night heron(Nycticorax nycticorax)
Yellow-crowned night heron(Nyctanassa violacea)
Wood ibis(Mycteria americana)
White-faced ibis[1](Plegadis chihi)
Glossy ibis[1](Plegadis falcinellus)
Double-crested cormorant(Phalacrocorax auritus)
Anhinga(Anhinga anhinga)
White ibis(Eudocimus albus)
Cattle egret[2](Bubulcus ibis)

Solitary Nesters

King rail(Rallus elegans)
Virginia rail[1](Rallus limicola)
Sora[1](Porzana carolina)
Black rail(Laterallus jamaicensis)
Yellow rail[1](Coturnicops noveboracensis)
Limpkin(Aramus guarauna)
Whooping crane[1](Grus americana)
Sandhill crane(Grus canadensis)
American coot[1](Fulica americana)
Common gallinule(Gallinula chloropus)
Purple gallinule(Pophyrula martinica)
American bittern(Botaurus lentiginosus)
Least bittern(Ixobrychus exilis)

1/ Feeding/loafing use only
2/ Nesting only---species feeds in upland areas

Colonial Nesters

Nesting Requirements

Colonial nesting wading bird species generally require a tree-shrub nesting substrate, although in Texas they have been known to nest on the ground as well as in shrubs and trees (Chaney et al. 1977). All of the species listed on Table 1 will nest together in mixed colonies in varying percentages although some pure colonies of great blue herons (Ardea herodias) do occur in inland areas (Thompson 1977). Chaney et al. (1977) noted as many as eight species nesting together. Meanley (1956 and 1972) reported a colony of little blue herons (Florida caerulea), snowy egrets (Leucophoyx thula), great egrets (Casmerodius albus), green herons (Butorides virescens), and anhingas (Anhinga anhinga) nesting at Swan Lake, Arkansas. Gersbacher (1939) reported large numbers of great egrets, double-crested cormorants (Phalacrocorax auritus), great blue herons, black-crowned night herons (Nycticorax nycticorax), and anhingas nesting together at Reelfoot Lake (colony now extinct; Gersbacher 1964).

Nesting substrate in Southern freshwater wetlands generally can be expected to consist of bald cypress, tupelo gum (Nyssa aquatica), swamp privet (Forestiera acuminata), black willow (Salix nigra), button-bush (Cephalanthus occidentalis) and other Southern swamp shrubs and trees (Bent 1926; Meanley 1972). Great blue herons have been known to nest in pecans (Carya illinoensis) in Texas (John Smith 1976, Texas Parks and Wildlife Department, personal communication). The birds generally will build their nests at or near the top of the canopy at heights ranging from

1-30 meters, depending on the nesting substrate. They select secluded sites for their colonies that offer protection from predators and isolation from humans. Frequently they nest on islands, or the sites will have insular characteristics such as being surrounded by impenetrable marsh or thickets. They also usually nest near their feeding areas, but if hard pressed for nesting sites they will select sites several miles away. Scharf (1976) reported a large colony of waders which nested on an isolated island in Lake Erie but that flew as far as 30 kilometers away to feed.

Nesting chronology varies with locality, but generally begins for all species by March and all young have usually fledged by September. Cattle egrets (Bubulcus ibis) are the latest nesters, will be the last species to enter a heronry, and have increased in population while other species declined. This may be attributed to the fact that they are wetlands nesters but upland feeders, and therefore do not suffer the limitations imposed by diminishing wetlands (Davis 1960). Great blue herons will nest in February in most localities. In south Florida, most species are late winter-early spring nesters, especially wood ibises (Mycteria americana) (Kushlan 1976; Browder 1976). Roosting areas are usually in the same area as the nesting colony.

Feeding Requirements

All wading herons, egrets, and ibises feed almost solely on fish, crustaceans, amphibians, and insects (Martin et al. 1951). These birds were much persecuted as being predators of game fish until research (Cottam and Uhler 1945) proved that 75% of their diet consists of non-commercial fish, frogs, snakes, crayfish, mice, and similar prey. Obviously, they are feeders in an aquatic environment, and any decrease in wetlands area decreases these species' feeding habitat proportionally.

Solitary Nesters

Nesting Requirements

Rails, limpkins, bitterns, gallinules, coots, and sandhill cranes are all prone to nest in isolated pairs in tall marsh grasses, cattails (Typha latifolia), and sedges (Bent 1926). They build their nests in secluded spots above the water level by matting together the vegetation or by fastening the nest to the stems of vegetation. They will also nest on old stumps, in mats of vines, or low shrubs. They too will choose insular situations for nest sites, as this affords them protection from predation and disturbance, but they hide their nests carefully in comparison to the colony nesters.

These species usually begin nesting in March and all young fledge by August. These birds roost in the same habitat in which they nest: tall marsh grasses, cattails, sedges, and low shrubs.

Feeding Requirements

Feeding requirements are varied for this group of birds. Sandhill cranes usually are vegetarian, consuming marsh vegetation such as chufa (Cyperus esculentus), bulrush (Scirpus spp.), waterlily (Nymphea spp.), and other wetland plant leaves, stems, tubers, and seeds. They do eat some insects, frogs, snakes, and toads (Walkinshaw 1949).

Limpkins almost always only eat the soft bodies of snails, and rails are solely consumers of insects and crustaceans (Martin et al. 1951). Gallinules are opportunists and change with the season. In spring they consume 35% and in fall 83% plant foods (grasses, millet (Echinochloa spp.), and rice (Oryza sativa). They will also eat aquatic insects, mollusks, and other insects (Bent 1926). All species are directly dependent upon wetlands for their food sources.

HABITAT: WHAT CAN BE DONE

Given the background of massive, universal impact on Southern wetlands and the wildlife that inhabits them, a very gloomy picture emerges. "Most land and water investments are terribly permanent. What is done cannot be undone by us or our children" (Clawson and Fox 1961). The wetlands that have become agricultural lands, reservoirs, and urban sites in years past will undoubtedly remain as they are now. Even as most biologists realize the vital need to protect our remaining wetlands, pressures from both private and public sources to alter our wetlands are still felt. In Mississippi less than five percent of the productive hardwood bottomlands in the Delta area remains, yet private land owners still are draining and clearing as fast as permits are available.

Section 404 regulations giving the U. S. Army Corps of Engineers biologists authority to determine wetlands areas before permits will be issued for land alteration should slow down the destruction of more wetlands. New guidelines are being established, and research is under way at WES to determine indicator species and other identifiers of wetlands and transition zones that will be extremely useful to field biologists responsible for permit determinations.

Where does the present situation leave the

wading bird populations so badly decimated by pesticides, habitat destruction, and human encroachment? Remedies are not fast and clear-cut. Realistically, the manager of a wetlands area must be prepared to accept the fact that he cannot expand the wetlands outside the land he can control (refuges, management areas, game farms, commercial forest lands). Therefore he will have to settle for limited results. But the cumulative efforts of all managers could be a modest expansion of wetlands in the South that would increase available habitat not only for the wading birds in question, but other marsh users such as the economically attractive waterfowl species.

Several habitat development and management practices will need to come into use when consideration is given to providing freshwater habitat for wading birds. First, all existing wetlands areas should be protected and managed very carefully to ensure that their quality is not decreased by pollutants (sediments, chemicals, pesticides, excess nutrients) from outside sources. This is a difficult assignment, since it would require enforcement of water quality standards and education of surrounding land owners as to proper conservation and farming practices to prevent erosion, over-fertilization and over-spraying of chemicals and pesticides.

Second, permanent wetland areas should be created where none exists that meet the following requirements: 1) varying water depths with large areas of shallow marsh, 2) good water quality, and 3) year-round protection, especially in spring and summer. Temporary greentree reservoirs and flooded fields are an established practice for wintering waterfowl. Something of this nature on a permanent basis is needed for wading birds that will provide a habitat for the prey of wading birds. The key here is to provide more feeding habitat, as nesting habitat has usually not been found to be a population-limiting factor. A temporary water-retaining structure for waterfowl only helps wading birds during the months of actual flooding (winter). The rest of the year, and especially during the critical nesting season when quality foods are needed in abundance, flooded habitat is simply not available to wading birds in a management system for waterfowl.

Third, some areas on all refuges and management areas should be converted to permanent shallow water ponds and marshes for year-round use by waders as feeding areas. Deeper water is needed for cormorants' fishing.

Fourth, a very important requirement for all species is clean, clear water so that the birds can see their prey. Rivers, lakes, streams clouded with sediment and contaminated with chemicals are useless to visual feeders. It is no accident or coincidence that the colonies and populations of herons and egrets decline in the Mississippi River system from north to south (Thompson 1977). Pesticides and sediment loads in the river which increase as it flows southward have taken a deadly toll on historic populations.

Finally and of equal if not greater importance, is the absolute necessity of providing protection in wetlands areas from humans and predators that would disturb a wading bird colony. Signs prohibiting entry to colony areas, education of the public, fences, and tough laws are required to ensure the protection these species must have to exist. Shooting of nesting herons and egrets occurs for sport and for malice, and must be controlled by law enforcement officials.

SUMMARY

In summary, neither wetlands nor wading bird populations will ever regain what has been lost to man. Only by preservation and management of existing wetlands and as much expansion as is possible of historic wetlands will wading birds survive and increase. Pesticides, excess nutrients, and sedimentation have taken tolls in bird populations and disrupted their reproductive processes. Human disturbances have caused tremendous upheavals in nesting colonies. Five practices are recommended for management of wading birds in freshwater wetland habitats:

1) All existing wetlands should be preserved and managed
2) New permanent wetland areas should be created
3) Expansion of some temporary wetlands into permanent areas on refuges and management areas should be done as rapidly as possible
4) High water quality should be maintained in all wetlands areas to ensure feeding habitat for fish-eating birds
5) All areas <u>must</u> be protected from humans and predators to be of real value to wading birds year-round, but especially during the nesting season (February-September).

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Census Techniques for Forest Birds

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Abstract.--The spot-mapping method is generally acknowledged to be the most dependable of the several census methods for forest birds in the breeding season. Transects and point counts, especially when well standardized and corrected for biases, may be preferable if large areas must be sampled in a short period of time.

INTRODUCTION

With the increasing emphasis on nongame birds as an important natural resource, forest managers are looking for efficient ways to document their populations, for both research and educational purposes. This paper will summarize and comment upon the principal techniques that have been used successfully at various seasons of the year.

CHOICE OF TECHNIQUES

Unfortunately, there is no quick and easy way to measure bird populations in forest habitats. Indices that can be used for comparing one plot with another are relatively easy to obtain, but it is seldom practical to attempt an actual head count on even a small sample plot of 6 to 10 hectares. Almost any attempt to obtain a population estimate must be a compromise between the degree of accuracy sought and the amount of time and trained personnel available.

CHANGING POPULATION

The average adult songbird has only a 40% to 60% probability of being alive one year later. For young birds, the likelihood is considerably less. Thus, bird populations are continually changing through production of young, death of young and adults, local wandering in and out of study plots, and for most species, migration. Mortality of young birds is highest in their first one or two weeks after fledging. Mortality of adult birds of most species is highest during migration, or periods of severe weather, which are most likely to occur in midwinter.

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OPTIMAL SEASONS FOR CENSUSING

Bird census work can be done with greatest accuracy during the peak of the breeding season, which for most species is in May and early June in the Southeast. At this time, most male birds are defending territory and are strongly attached to a very small area of a specific habitat for four or more weeks. During the peak of the nesting season most male birds are in song every day, at least during early morning hours, and are much more easily detected than later in the summer. In winter and during the migration seasons, birds are much more mobile and less attached to a specific habitat type.

DOCUMENTARY STUDIES

Any census work undertaken should be initiated with one or more particular objectives in mind. If one wishes only to document the species that are using a forest, help can frequently be enlisted from local experienced amateurs.

Since I work primarily with amateur ornithologists on cooperative programs to monitor populations, I naturally think of the vast resource of qualified help that is available to assist with bird population studies.

For example, nearly all of the national wildlife refuges have lists of birds of their area that are available for free distribution to visitors. Some of these lists were compiled entirely by amateur volunteers, and in almost all cases amateurs contributed many of the records. Most of the national parks also have publications on their wildlife resources. Comparatively few national, state, or other forests, however, have made lists of birds and other fauna available to the public. I believe that provision of such lists is one of the first steps toward arousing public

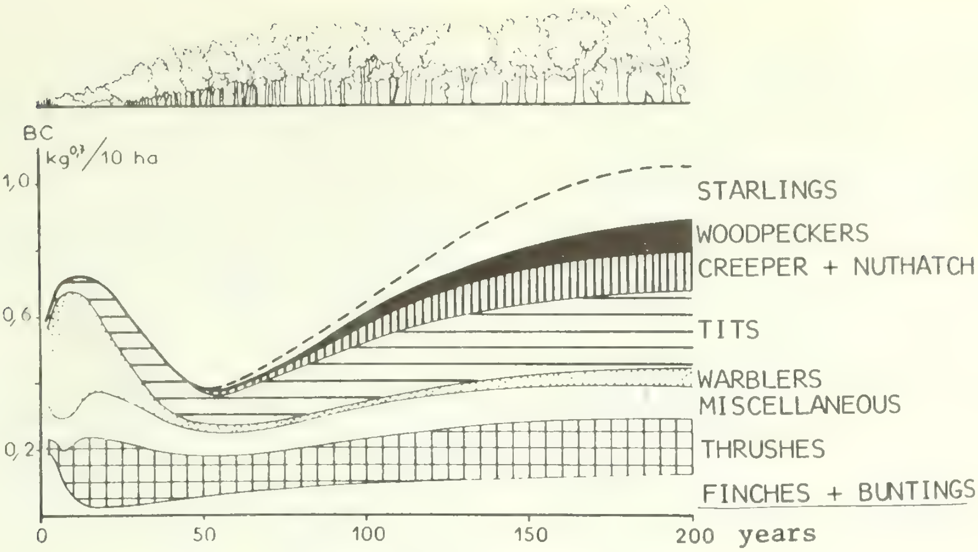

Figure 1.--Changes in consuming biomass as represented by the principal bird families during a 200-year succession in an oak forest in France. From Ferry and Frochot (1970).

interest in the biological resources of a forest. Volunteer cooperators should be able to prepare such lists, and furthermore, assist later with quantitative studies of bird populations.

Parts of many of the national and state forests are included within 15-mile diameter Christmas Bird Count circles. An easy way to enlist volunteers to assist in the preparation of a list of species for a specified forest would be to contact the Christmas Count compiler (whose name and address are always given in the published report in American Birds) and get from him the name of the person or persons responsible for covering the forest. By asking this observer to keep a separate record of birds seen in the forest, one can not only start to build up a file of information on the winter avifauna of the forest, but one can also generate the interest necessary for continued assistance through all seasons of the year. If help is needed in documenting presence of endangered species, this also can often be done by enticing qualified amateurs to join in the search.

COMPARATIVE STUDIES

For comparing bird populations of two or more sites, we must turn to methods that will yield numerical estimates of bird population, or at least index values. Such studies would include the need to document populations before and after some particular management program, timber harvest procedure, fire, pesticide treatment or other event that might influence bird populations (Kendeigh 1947, Hager 1960, Michael and Thornburgh 1971, Conner et al. 1975, Webb et al. 1977, Schweitzer 1978). Such studies can also be used to document population changes during successional stages (fig. 1) or during recovery from fire, surface mining, or other ecological changes (Johnston and Odum 1956, Ferry and Frochot 1970, Hamilton and Noble 1975, Shugart and James 1973, Shugart et al. 1975). Comparative studies can also be used to assist management decisions. For example, one may wish to choose among several areas for a particular management program, or even for preservation of a unique ecosystem such as to provide habitat for a particular endangered or threatened species.

Williamson (1970), for example, has used spot-mapping censuses to show that density and diversity of bird-life in coniferous plantations can be increased by providing a fringe of deciduous trees or leaving small "island refuges" of scrub or deciduous trees. Such a practice might even provide additional benefits by reducing insect damage.

BREEDING SEASON TECHNIQUES

Spot-mapping Census

The spot-mapping technique, also called the plot census or, simply, mapping census, was first employed in North America by Williams (1936) and in Sweden by Enemar (1959). Basically, this technique consists of making 8 or 10 census trips through a plot of known size, and preferably of uniform habitat, that has been surveyed and mapped with a grid

system. On each visit the position of each bird seen or heard is recorded on the plot maps. Kendeigh (1944), Lack (1937), and Udvardy (1957) give good historical accounts, describe the method in detail and include comprehensive bibliographies. An important feature of the spot-mapping technique is to designate with appropriate symbols those individuals of a species that are heard singing at the same time (simultaneous registrations). These, in conjunction with clusters of single registrations, make it possible to outline the approximate territorial limits of each male bird and make a reasonable estimate of the total number of territorial males of each species present in the area (fig. 2).

This technique has now been widely adopted in Europe and North America. Procedures have been standardized by the International Bird Census Committee (1970a,b) so that results obtained in different countries can be compared. Spot-mapping has been widely used in England since 1962 to monitor bird population changes (Batten and Marchant 1977a,b). A quantitative description of the habitat (James and Shugart 1970) is now a standard feature of many of the Breeding Bird Censuses in forest habitats published in American Birds.

The spot-mapping method is the technique used by most census workers (Kendeigh 1944, Bond 1957, Oelke 1974, Yui 1974). It is generally acknowledged to be the most accurate of the various bird census methods because: 1) it gives the greatest opportunity to record all species that are breeding in the area, 2) it most closely approximates the absolute number of breeding pairs, 3) there is a minimum of error in estimating whether the birds recorded are within or outside of the plot boundaries, and 4) observer bias is minimized. The chief disadvantage of the technique is the amount of time required to set up the plot and conduct a minimum of eight census trips.

Critique

The spot-mapping method is not without its pitfalls. Most plots censused are within the 6 to 20-hectare range, and do not permit accurate measurement of territories of wide-ranging species. Year-to-year variation in plots as small as 6 ha is greatly exaggerated by birds that move short distances into or out of the plot boundaries from one year to the next.

Svensson (1974) had 58 persons with various levels of experience estimate breeding populations using census maps from 37 plots. He reported that the coefficient of variation ranged from 6% to 56% (15 to 30% for most plots), and that it varied among species (from 16% to 36%). Variability would have been less if the participants had had field experience in the plots. Svensson concluded that considerable variation does exist among persons in the evaluation of species maps, and he recommends that when plots from different

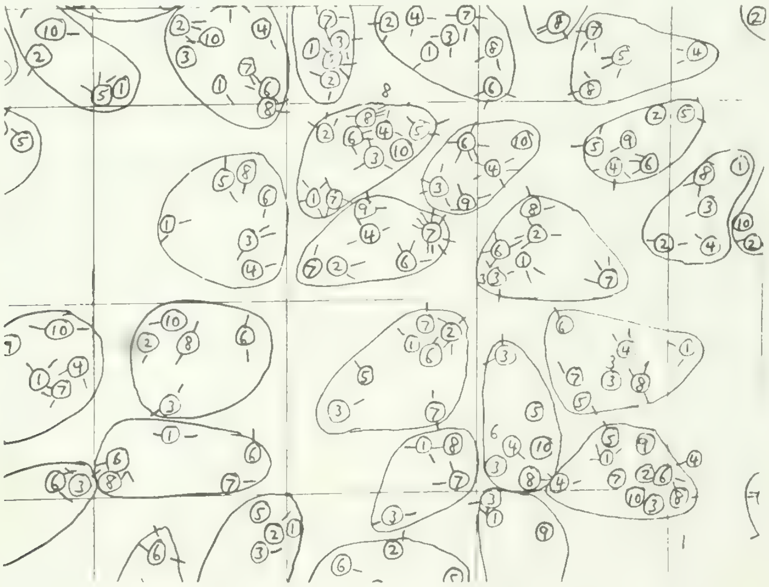

Figure 2.--Section of species map for Red-eyed Vireo at the Patuxent Wildlife Research Center. Numbers designate the 10 trips. Singing males are circled; simultaneous registrations are indicated by pointers. Each square is 1 ha.

habitat types or different regions are compared a check should be carried out on a sample of maps to see if there are any differences in the evaluation procedures applied.

Nilsson (1977), in an evaluation of the mapping method, believed that more than 10 visits, and perhaps as many as 20, may be required for accurate censusing of certain difficult species. He suggested that the number of visits might be reduced if more time were spent on each visit.

Berthold (1976) published a comprehensive critique of bird census methods with emphasis on the mapping method. He concluded that there are almost no methodologically perfect tests of census methods; that errors of 50% or more are common; and that although many errors and sources of errors have been recognized in the literature, they have not sufficiently been taken into consideration. He recommended abandoning relative census methods in favor of more absolute methods, and he proposed using nest finding and banding to supplement mapping. He stated that census methods should be more standardized and that calculations or justified estimates of errors should be included in published results. A. J. Erskine, who has translated Berthold's critique into English for the Canadian Wildlife Service (unpublished manuscript), points out that "Berthold is not himself a worker in bird census studies but rather an environmental physiologist accustomed to the careful regulation of variables often possible in laboratory studies. Many of the criticisms he advances are long familiar to census workers, whose experience would have prevented some of the sweeping generalizations in his review." Berthold does include an excellent bibliography, especially of German, English, and Scandinavian titles.

The mapping method was recently criticized by Best (1975) as not yielding results that can be interpreted consistently by different experienced observers; but this criticism was unfair because the author apparently failed to follow standard procedures and neglected to obtain data on simultaneous registrations of the single species considered--data that are essential to proper interpretation of the results.

To fairly test reliability, different observers must do the field work as well as determine the number of territories on each map. This was done in a mature floodplain forest plot at the Patuxent Research Refuge in Maryland by Robbins and Bridge. They conducted independent censuses of 8 visits each in a 40 ha plot from 15 May to 3 June 1962. One observer censused from north-south trails through the plot while the other used east-west trails. After making independent estimates of the breeding population, the two observers combined their maps and made a revised estimate based on all 16 visits. With 8 visits the observers had detected 89% and 92% of the birds that were detected on 16 visits.

Diehl (1974), who made 27 and 21 visits, respectively, to two grassland plots totaling 43.5 ha found that between 32% and 44% of the pairs present were detected on a single visit, and 95% to 98% on one or more of 10 visits. However, a great many of these birds were detected on only one or two visits and would not have been recognized as distinct pairs; thus while nearly all of the pairs had been observed and recorded, the population estimates from 10 visits would have been only 53% to 66% of the number of pairs present.

Other authors (Davis 1965, Jones 1974, Erskine 1974) have discussed problems in using the spot-mapping technique for certain species that are difficult to census, such as those that do not sing regularly, are not territorial, or range over areas much larger than the size of most census plots. Nevertheless, spot-mapping is still the most generally accepted method and the one most frequently used to calibrate the results of less time-consuming, but relatively less accurate methods.

Census Summaries

Three catalogs (Erskine 1971, 1972, 1976) have summarized the results of 228 Breeding Bird Censuses that have been conducted in Canada. Censuses that have been published from 1937 through 1977 in American Birds have been put on magnetic tape at the Migratory Bird and Habitat Research Laboratory where they provide a valuable comparative resource that may be accessed either by habitat, by bird species, or by a number of the other variables that are included in the computer record. This file presently contains information on 1,101 plots.

Transects

The transect method involves counting birds on one or both sides of a line through one or more habitats; in most instances either the width of the transect is defined or the distance to each bird encountered is estimated. The transect method was first used extensively in the United States in 1906-09 by Forbes and Gross (Graber and Graber 1963) and in Finland in 1941-56 by Merikallio (1958). In both instances, the transect results were used to estimate total populations by habitat for an entire state or nation. The Forbes and

Gross study was later repeated by Graber and Graber (1963) to show bird population changes over a 50-year period.

One advantage of the transect method is that it may be used throughout the year, but the results are less accurate outside the breeding season. Another advantage is that a relatively large area can be sampled in a short time. Flack (1976), for example, used 150-foot-wide transects to compare breeding bird populations in 41 aspen forests in 9 western states and provinces, 1966-69.

The chief disadvantage of the method is that a single coverage of a transect does not permit a good estimate of the number of birds missed. Anderson and Pospahala (1970), using data from 1600 miles of transects, generated a curvilinear (quadratic) equation to show the fraction of waterfowl nests missed at various distances from the center line of the transect; but they pointed out that to adequately correct for the number of fixed objects missed one needs a large sample and one must also make the assumption that all of the objects closest to the center of the transect are detected.

Emlen (1971) also has considered how the error inherent in the transect count may be minimized by first estimating the lateral distance to each bird encountered (fig. 3), and then deriving a coefficient of detectability. He assumes that no bird close to the observer goes undetected. In actual practice, the number of birds within a few meters of the transect line that are undetected may be quite large (Järvinen and Väisänen 1975), especially in a mature forest habitat. Even during the height of the breeding season there is an enormous difference in singing behavior and conspicuousness among the various species. A noisy, active species such as the Tufted Titmouse may be recorded on 68% of the visits if within 50 meters of the observer, whereas species such as the Ruby-throated Hummingbird, Worm-eating Warbler, and even the American Redstart may be recorded only 36% to 39% of the time (Stewart et al. 1952, pp. 269-270). Emlen (1977) estimated the number of unrecorded males of common species by running each transect five times, plotting all singing birds on maps, outlining the territory of each, and determining what European workers call the "effectivity" of a single trip for each species. He then used the computed effectivity for correcting his breeding season transect results.

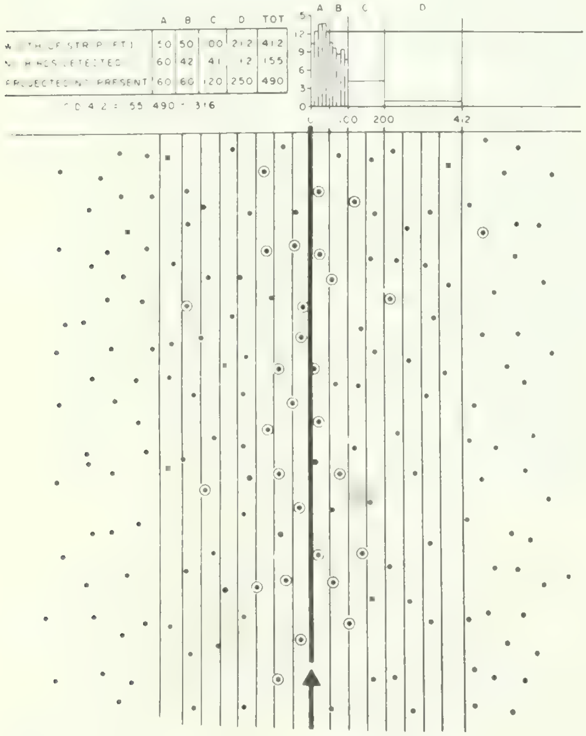

Figure 3.--Schematic model showing birds detected (circled dots) at various distances from the transect (heavy line). From Emlen (1971).

The transect method is quite effective for comparing the abundance of a given species among two or more plots of similar habitat. Also, unless visibility is strongly influenced by the structure of the habitat, the transect method may be used to compare abundance of a given species from one habitat to another. It is not, however, a desirable method for comparing abundance of two species that may not be equally conspicuous, unless appropriate corrections are made, species by species. These corrections can be made by taking a series of transect counts through plots where the population has been estimated by other methods (Ferry and Frochot 1970), Enemar and Sjöstrand 1970).

Although most transect workers record birds per kilometer (or per mile) or per square kilometer (or per 100 acres), a few have preferred to use units of time such as birds per 10 hours (Colquhoun 1940).

Transects are especially effective along hedgerows and wood margins where it may seem impractical to establish mapping plots or make point counts. Johnston (1947) did, however, use spot-mapping in two isolated woodlots to compare distribution of forest-edge and forest-interior species.

The IPA or Point Count Method

The IPA (Indices Ponctuels d'Abondance)

method was developed by Ferry and Frochot (1970) as a means of obtaining indices of abundance for comparing bird populations of different habitats (or of the same habitat in different locations) during the breeding season.

The IPA counts by the French ornithologists consist of the establishment of a network of points regularly distributed through the habitat to be studied. The observer then stands at each designated spot for 20 minutes in the early morning in good weather and notes all birds heard and seen. Each spot is censused twice in the breeding season. The higher of the two counts of pair numbers is used as an index of abundance for each species. Each singing male, occupied nest or family of birds out of the nest counts as one pair, while a bird merely seen or heard calling counts as half a pair. The efficiency of a 20-minute stop seems satisfactory to the French investigators because during the last 5 minutes only 3% more species and 9% more individuals were recorded in forest habitats.

Ferry (1974) quotes Schwartz (1963, p. 139) as stating that with a sample of 30 or more the mean may be compared with another number, whatever the type of distribution. Thus, it is possible to calculate whether the mean IPA of a species is statistically different from zero, and so have an objective way of eliminating species whose occurrence in the habitat is due to chance or whose presence is unimportant. (In actual practice, of course, some of the scarcer species may be the ones most in need of attention from forest managers.) Ferry (1974) has determined which species have statistically significant population differences in two habitats as indicated by the IPA method. He has then computed a percentage of difference as a final comparison of the two plots. In this way, numerical similarity indices could be computed among an entire matrix of different plots with a minimum of field work. Ferry also points out that by conducting IPA counts within a mapping census plot, one can determine the effectivity of the IPA method, species by species, and thus obtain correction factors to convert indices to population estimates.

In Denmark, Jørgensen (1974) conducted 81 IPA censuses on 8 mornings from mid-May to mid-June. The 13 1/2 hours of effective field work was about 50% less than would have been needed for covering one census plot by the mapping method. Jørgensen compared the density of each species among different habitats, using the Mann-Whitney U-test. He concluded that the IPA method was well suited to a study of forest succession, in which it is desired to make statistical comparisons. He summarized habitat utilization (based on 15 to 18 counts in each habitat) in terms of a list of dominant species, each comprising 5% or more of the registrations, and sub-dominants (2% to 5%). Then, using only the dominant species, he computed similarity indices among the various habitats using the formula $s=2c/(a+b)$ where s is the index, a and b are the numbers of species in each sample, and c the number of species common to the two samples.

In the United States, the IPA method has been further refined by Whitcomb and Robbins 2/ who make three 20-minute counts (each composed of four 5-minute segments) at each point. The three samples are taken at different times in the nesting season (generally early, middle, and late June) and at three different periods in the early morning hours in order to maximize the likelihood of recording all species present.

Density-Frequency Relationship

Blondel (1975) has introduced a further modification of the IPA method (Echantillonnage Frequentiel Progressif: EFP). The EFP method uses the presence or absence of a species on each of the 20-minute IPA counts to determine frequency of that species in each plot (fig. 4). Comparison of the IPA and the EFP figures allows one to determine for each species the relationship between its density and its frequency. The frequency of a species is shown to be closely correlated with the logarithm of its density (fig. 5); the lower the frequency the better the correlation. "Thus, frequencies of occurrence can be used as an objective measure of the number of individuals included in the community." Rotenberry and Wiens (1976) found a similar correlation between density and frequency using roadside transect (BBS) data.

Blondel claims that the EFP method, which is highly standardized, is very useful for a rigorous statistical interpretation of data. He used the EFP method to calculate ecological profiles and niche breadth for each species. He analyzed the structure of bird communities according to the structure of the vegetation. For each community, he determined the species richness, the species diversity index (H'), the equitability (J'), and the level of fit to Galton's log-normal model. He also discussed the influence of reforestation on bird communities. "In many instances, conifer plantations, especially Cedar (species not stated), seem successful in the rebuilding of communities." Blondel concludes that the

2/ In preparation

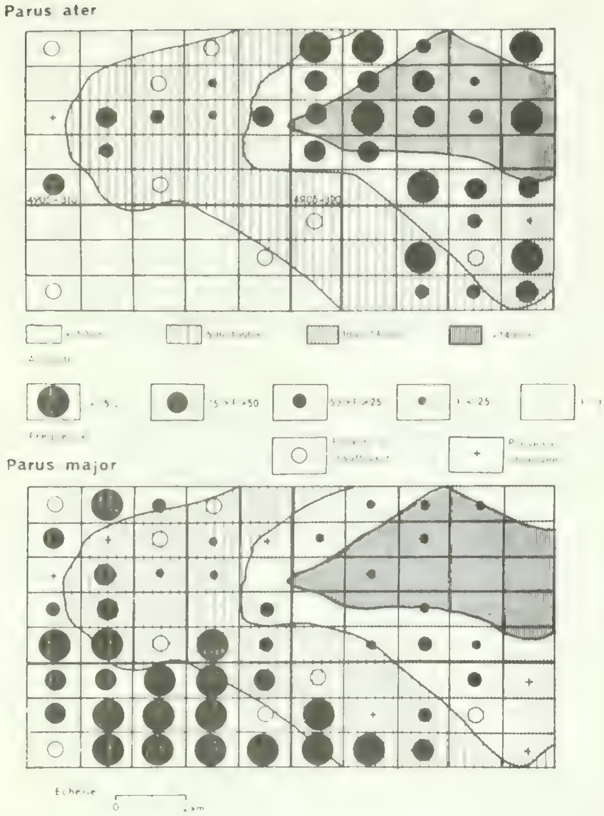

Figure 4.--EFP maps showing distribution of Coal Tit (above) and Great Tit with relation to elevation. Frequency, as shown by size of the dots in the legend, is based on an average of about four 20-minute IPA counts in each of the small rectangles. From Blondel (1975).

standardized and time-saving EFP method "seems very well adapted to solve problems of theoretical and applied ecology at the community level, and can be used fruitfully for environmental monitoring."

Comparison with spot-mapping

In comparing point counts (IPA) with mapping census in Białowieża Forest in Poland, Tomiałojć <u>et al</u>. (1978) found that point counts overestimate the population when the density is low and underestimate when density is high. IPA counts also require better observers and encounter more problems separating migrants or other non-breeding birds from breeding individuals than do mapping censuses.

Combining transects and point counts

Bond (1957) used a method that was essentially a combination of the transect and point count methods to compare bird populations in 64 upland hardwood stands in Wisconsin. After entering a woodland he walked about 50 m along a transect line. At this point he stopped for 5 minutes and counted all birds seen and/or heard ahead of him. He then walked ahead slowly for 5 minutes, averaging 150-175 m. He repeated this procedure until he had 5 sample 10-minute counts from each forest interior. Two early morning visits were made to each woodlot and the highest count for each species was used. These counts detected 76%, 78%, and 70%, as many pairs as were found by spot-mapping censuses in three of the same woodlands. Palmgren (1930) and Kendeigh (1944) found 81% and 63% of their birds in spot-mapping censuses were detected on the first two visits.

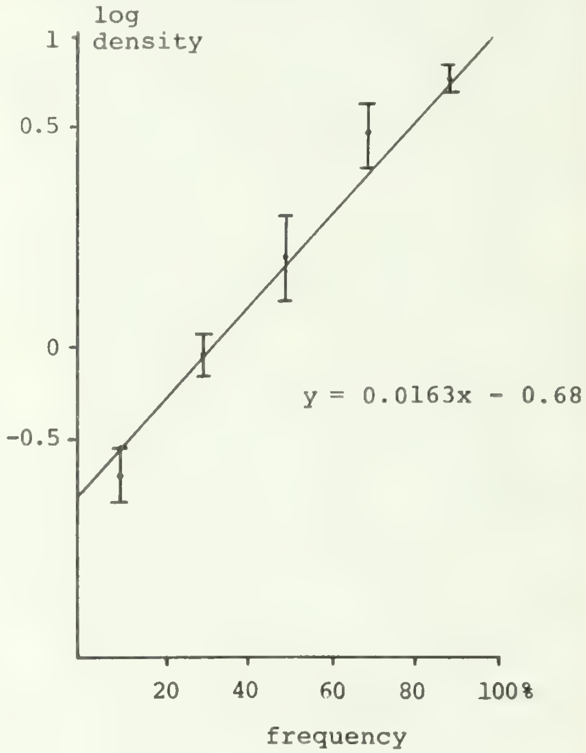

Figure 5.--Relation between frequency of detection and logarithm of numbers of individuals detected for 239 pairs of 57 species. Confidence interval, p =.05. From Blondel (1975).

Breeding Bird Survey

The North American Breeding Bird Survey (BBS) was developed by the U. S. Fish and Wildlife Service to monitor bird population changes in North America over a period of years (Robbins and Van Velzen 1967, 1969, 1974). Each survey route is a series of 50 3-minute point counts at 1/2-mile intervals along a 24 1/2-mile roadside transect that was selected by a random procedure. Coverage extends from one-half hour before sunrise to about 4 hours after sunrise and thus embraces the period of

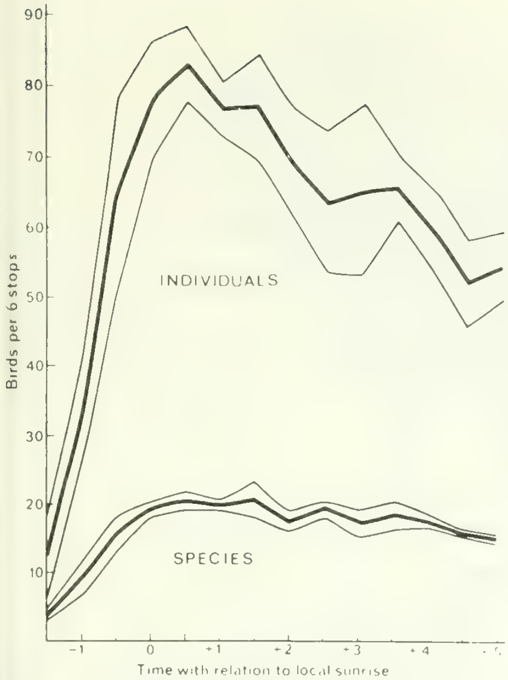

Figure 6.--Hourly variation in bird counts. The outer lines represent 95% confidence limits based on 4 days in June 1969. From Robbins and Van Velzen (1970).

greatest bird activity (fig. 6). At each of the 50 stops, all birds heard and all birds seen within one-quarter mile of the counting position are tallied. The BBS, which now embraces the populated areas of Canada and all of the United States except Hawaii, provides an annual sample from 1700 or more roadside transects. The results are widely used for documentary and research purposes, and are also available for comparison with intensive local population studies, such as Miniroutes that use the same method.

The BBS results are used primarily for statistical analysis of population changes over the years (fig.7) and for mapping of relative breeding densities throughout the North American range of a species (fig. 8). A ten-year summary of the BBS results is in preparation.

BBS Miniroutes

For intensive local studies, BBS routes can be laid out in a non-random way, so that all or most secondary roads within the area of interest are included in the sample (fig. 9). The term "Miniroute" results from a 25-stop instead of a 50-stop format. By using a shorter route, observers were able to complete

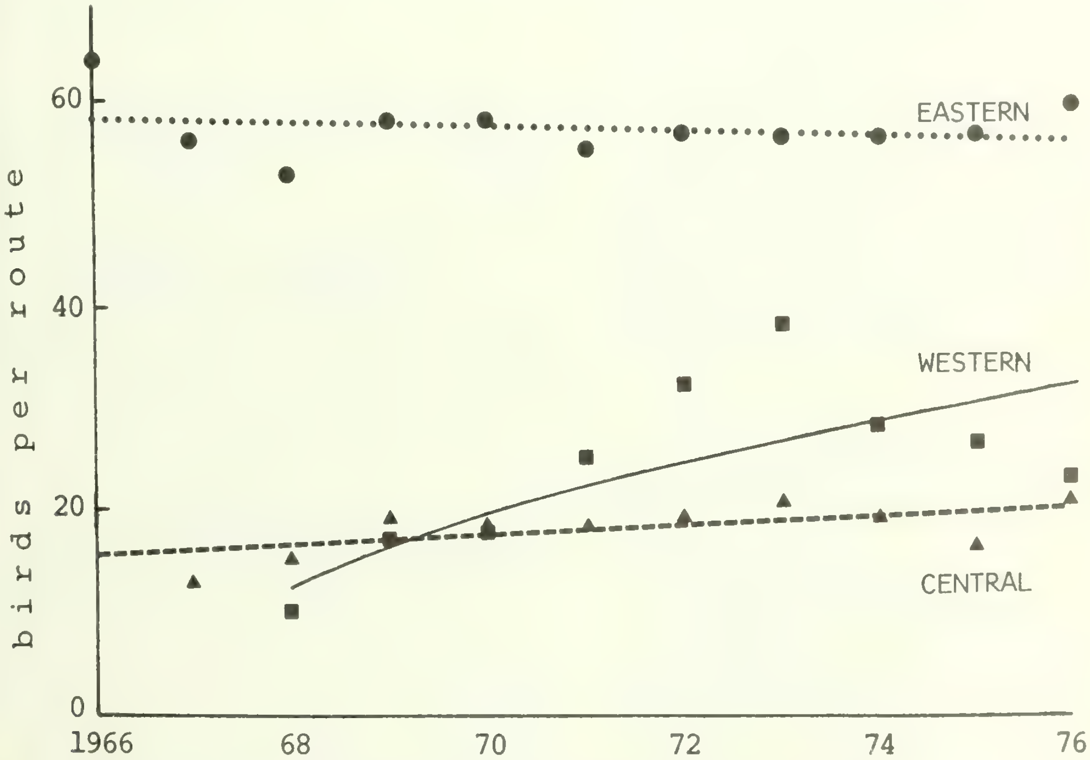

Figure 7.--Population trends in the Starling in the western, central, and eastern regions of North America. Data from Breeding Bird Survey.

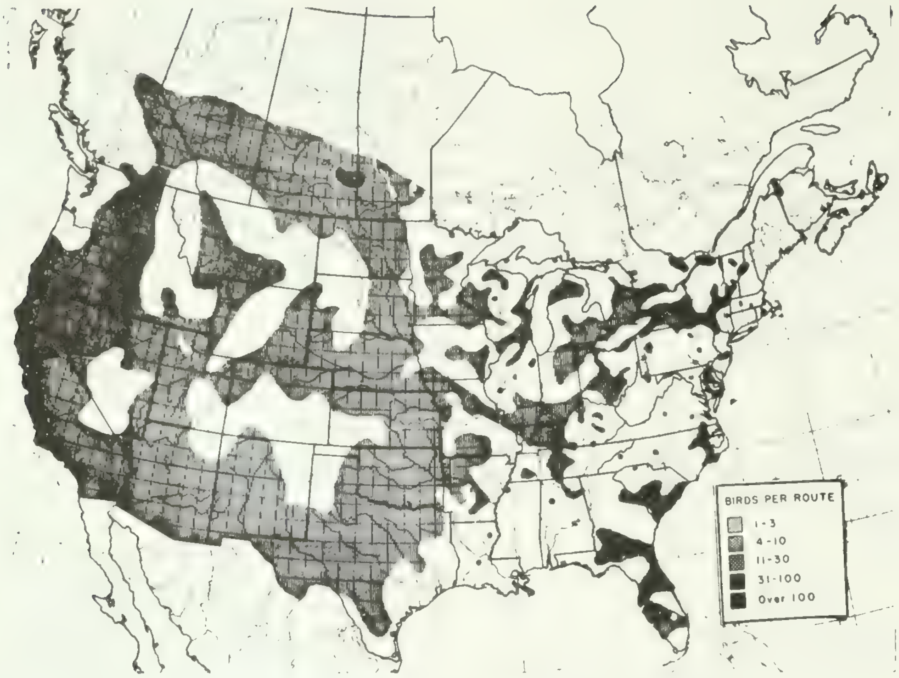

Figure 8.--Relative abundance of the Red-tailed Hawk in the 1968-70 breeding seasons. Data from Breeding Bird Survey.

Figure 9.--Map of Howard County, Maryland, showing locations of the mid-points of each 5-stop section of the network of Miniroutes.

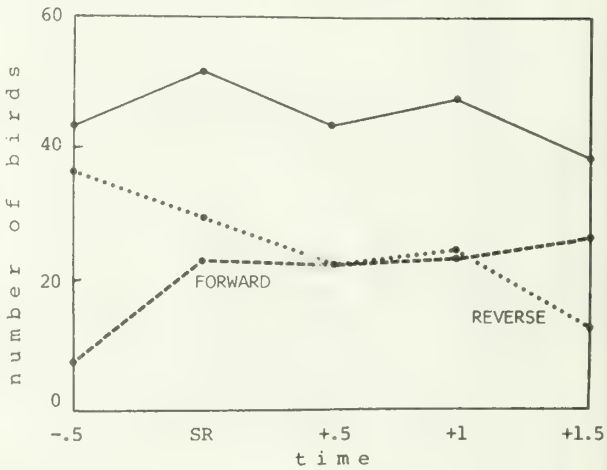

Figure 10.--Mean number of Red-eyed Vireos recorded per half hour on Howard County Miniroutes, 1973. The top line is the sum of the two coverages of each route. Time in hours is given with relation to local sunrise (SR).

their coverage before working hours in the morning. By covering each route twice (once in each direction) and combining the results of the two counts, most of the difference in activity resulting from time of day could be eliminated (fig. 10). Bystrak and others (Klimkiewicz and Solem 1974) used Miniroutes to map relative abundance of breeding birds throughout two Maryland counties (fig. 11) as part of a Breeding Bird Atlas program for these counties. Although the Miniroute technique was designed for roadside use, it could be applied with slight modifications to coverage of forested areas on horseback or by off-road vehicles, making it possible to map distribution of breeding birds over a wide area with a minimum of expenditure of time. Differences in bird populations could then be correlated with differences in vegetation obtained from aerial surveys or by ground

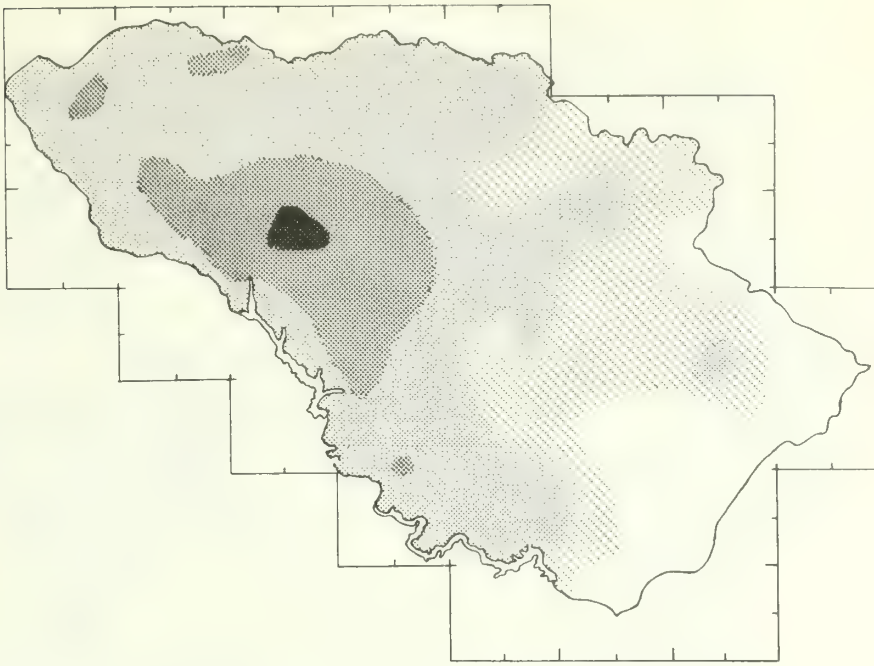

Figure 11.--Relative abundance of breeding Red-winged Blackbirds in Howard County, Maryland, plotted from the summation of two coverages of each of the five-stop segments shown in figure 9.

survey methods.

Breeding Bird Atlas

Breeding Bird Atlasing has become a popular pastime among bird observers in Europe during the past decade. Atlases showing breeding distribution maps for each species have recently been published for the British Isles (fig. 12), France and Denmark; and similar atlases are in progress in several other European nations (Belgium, Czechoslovakia, Finland, Federal Republic of Germany, Italy, Netherlands, Poland, Sweden, Switzerland). A more comprehensive mapping program involving all of Europe is planned for 1985-1988 using 50-km grids.

The initial purpose of preparing a Breeding Bird Atlas was to correlate bird distribution with that of plants as shown in the Atlas of British Flora (Perring and Walters 1962). In a government-sponsored program carried out through the British Trust for Ornithology and the Irish Wildbird Conservancy, observers visited every one of the 3,862 10-kilometer squares (100 square kilometers each) of land area throughout the British Isles during a 5-year period and reported presence or absence of each bird species (Sharrock 1976). Twelve transparent overlays, that must be ordered separately from the book, facilitate correlation of bird distribution with selected environmental factors such as July temperature, elevation, and distribution of moorland, sessile oakwoods (fig. 13), and standing fresh water.

In other countries, the sampling blocks have been of different sizes, depending upon the size of the total area to be sampled and the standard maps available. In France the sampling unit was 20 by 27 km (Yeatman 1976) while in Denmark it was a 5-km square (Dybbro 1976). In several countries (Belgium, Czechoslovakia, Poland) the method has been modified to include some indication of abundance rather than merely noting presence or absence.

No large-scale atlas has been attempted in the United States because the BBS provides an annual sample of changing abundance of each species and also gives a density of coverage roughly comparable with the projected European atlas of the 1980's.

Nevertheless, atlas studies have been initiated in several states (Illinois, Maryland, Massachusetts, Vermont, and parts of California and Michigan), generally using grids smaller than the 10-km British grid. These American atlas studies will provide a source of information on presence and absence of the various species in many forested areas.

The majority of atlas studies in the United States utilize a 5-km grid (6 blocks

Figure 12.--Breeding distribution of the Wood Warbler in the British Isles. Size of dots indicates the three atlas categories of possible, probable, and confirmed (largest dot) breeding. Map from Sharrock (1976).

Figure 13.--Transparent overlay from Sharrock (1976) showing distribution of Sessile Oak Woodlands. Compare with figure 12.

per 7 1/2 minute topographic map), but the Maryland Ornithological Society has changed from 5 km to 2 1/2 km "quarter blocks" (about 600 hectares or 1500 acres). The quarter blocks not only make it possible to pinpoint the location of rare species and others of special interest, but they also are much better for outlining areas where a particular species is not present (fig. 14) (Klimkiewicz and Robbins 1974). This feature takes on special significance in areas where commercial or residential communities are expanding or where habitats are being lost through various types of development. And in areas where large forests are being destroyed by changes in land use, quarter-block atlas data have been of immense value in showing to what degree various breeding species disappear when forested areas become fragmented into smaller tracts (fig. 15).

In situations where insufficient personnel is available to visit all atlas blocks, intensive coverage of a random sample

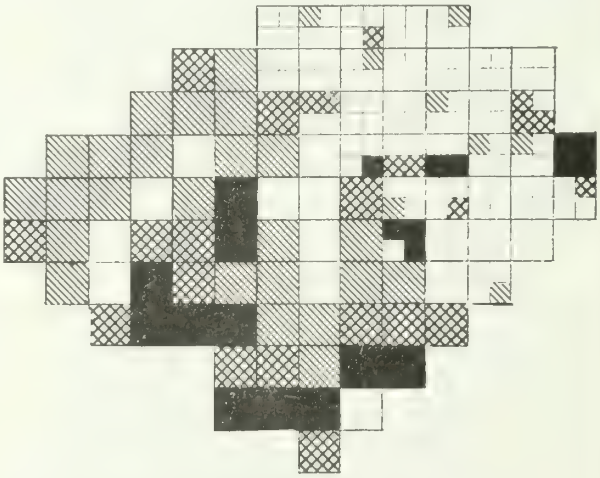

Figure 14.--Breeding distribution of Pileated Woodpecker in two Maryland counties in the Baltimore-Washington area showing the great improvement in precision when 5-km atlas blocks (Montgomery County) are replaced by 2 1/2-km quarter blocks (Howard County). The three atlas categories are indicated by darkness of shading.

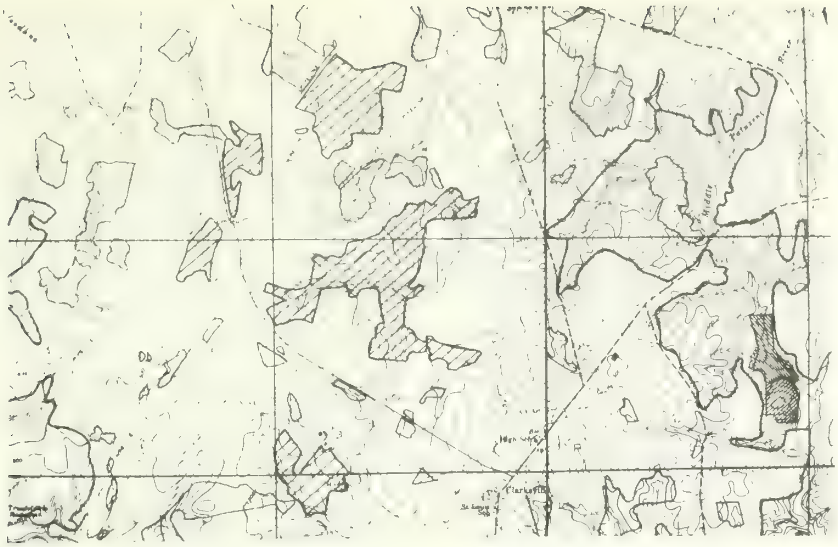

Figure 15.--Atlas quarter-blocks in Howard County, Maryland, showing forest fragments from which breeding bird species that require large tracts of forest interior are lacking. The species missing from the fragments still nest in the extensive woodlands along the Patuxent and Middle Patuxent stream valleys at the left and right edges of the map: Black-and-white, Worm-eating, Northern Parula, Cerulean, Kentucky, and Hooded Warblers, and others.

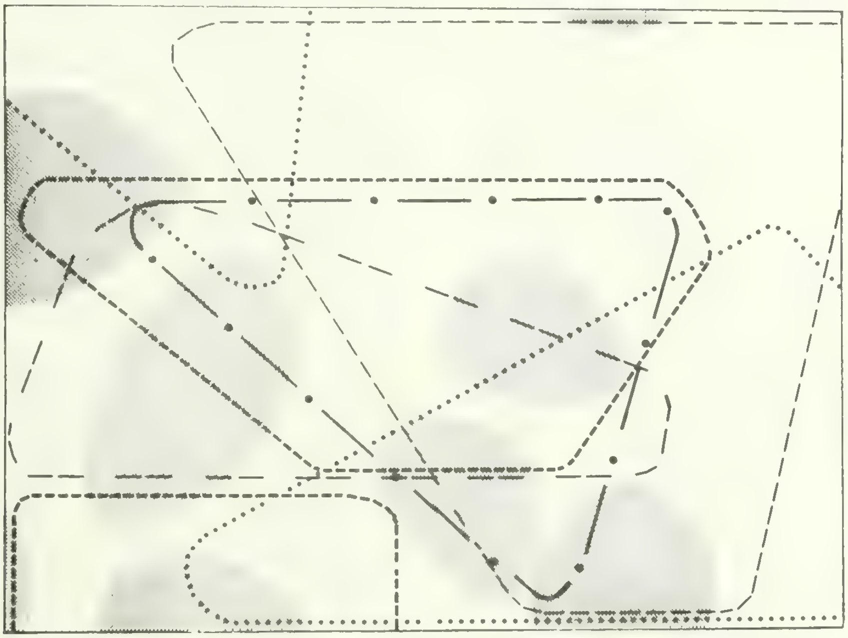

Figure 16.--Size comparison of Wood Thrush singing territories at Patuxent Wildlife Research Center determined from spot-mapping (shaded ovals), and home ranges of some of the same males determined by banding. Total area of this map section is 22 ha.

of small blocks is greatly to be preferred over casual coverage of much larger blocks.

The atlas technique yields high returns in the first day of field work in a given block. In 12 10-km blocks, each with 78 to 90

breeding species, an average of 72 species were detected in the first 16-hour day (Sharrock 1974); 40 of these species had been found in the first hour and 60 by the end of 8 hours. It is the added effort of searching for the important hard-to-find species and the accumulation of nesting evidence that is very time-consuming. Recent recognition that rare and/or disappearing species are most likely to be present in the largest forest tracts within a given grid should greatly reduce the effort required to locate such species.

Banding

Several investigators in the United States, Sweden, and France have used the marking and recapture of birds as a means of studying the effectiveness of other census methods (Stamm *et al*. 1960, Svensson *pers. comm.*, Frochot 1977).

Banding in itself is neither an efficient nor a highly accurate way of measuring entire breeding bird populations in forest habitats. It is, however, a very effective way to determine how many pairs of certain species are present. It also makes it possible to distinguish migrants from summer residents and, to some degree, non-breeding from breeding individuals. Color banding can be used to define the ranges of individual birds and also can point out errors in judgment that occasionally occur when the observer relies entirely upon the mapping method. Bear in mind, however, that home ranges of many species are much larger than their singing territories (Fig. 16).

Frochot (1978) has compared mapping, IPA, and banding techniques in the same oak forest plot of 100 hectares. Comparing the results for 12 common species, he determined a density of 49.9 breeding pairs per 10 hectares by the mapping method as compared with 47.0 by the IPA method (with appropriate corrections for conspicuousness). Banding data sufficient for computation of population estimates were available for only 4 of the 12 species, but for 3 of these 4 species the estimate from capture-recapture was higher than that obtained by either of the other two methods. Frochot reported that the IPA census required nearly 10 hours of prime time in the early morning, while the mapping census required 43 hours, and the banding study took 400 hours. The chief advantages of the capture-recapture method emphasized by Frochot are: 1) it permits a census of females and young as well as of singing males, 2) it can be used for testing mapping and IPA methods, and 3) it gives additional information about daily range and habitat utilization of the individual birds.

Nest Finding

To the uninitiated, nest finding appears to be the obvious way to determine accurately the breeding bird population of a forest plot. In actual practice, however, it is seldom possible to find enough active nests of a species to use this method as a measure of the breeding population--especially in forest habitats. While a nest census is effective for many colonial nesting species, such as herons and ibis, there are very few forest-nesting species that are colonial.

Nest censuses have been conducted successfully for a few species such as the Red-shouldered Hawk (Steward 1949, Henny *et al*. 1973). They have also been successful in a few habitats, especially in residential and park areas, where a high percentage of the nests are within 10 feet of the ground and where nests tend to be clustered in suitable strips of vegetation rather than scattered more or less randomly throughout the entire study plot. In a normal situation, nesting is spread over a period of at least 4 to 6 months and during this time nests are continually being destroyed or deserted and additional nesting attempts initiated. In the southern United States there is probably no one time when all members of a given species are nesting, so that even if it were possible to locate every nest during some particular week, this still would not be a census of that species in the plot. Tomiałojć (1974) studied nesting behavior of 17 pairs of Woodpigeons (*Columba palumbus*) near Wrocław in Poland and found that no more than 6 of the 17 had active nests at any one time (fig. 17).

A good example of a nesting study of a single species is a Wood Thrush investigation in a 14.4 ha Delaware woodlot by Longcore and Jones (1969). Systematic nest searches were conducted during a 3-month period in 1965 and again in 1966. Grid lines located at 150-foot intervals were traversed at least once every 3 days except for a 2-week period in July 1965. A total of 142 Wood Thrush nesting attempts were documented (fig. 18) of which 38% were successful. This study was supplemented by an intensive banding effort every 2 to 3 weeks during the 1966 breeding season. This effort resulted in 46 Wood Thrushes being banded. This study was directed primarily toward determining reproductive success rather than measuring the population, but it gives an idea of how much effort would be involved in gathering enough information about a single species to get an accurate measurement of the breeding population.

In summary, I do not minimize the importance of actual nest counts as a supplement to

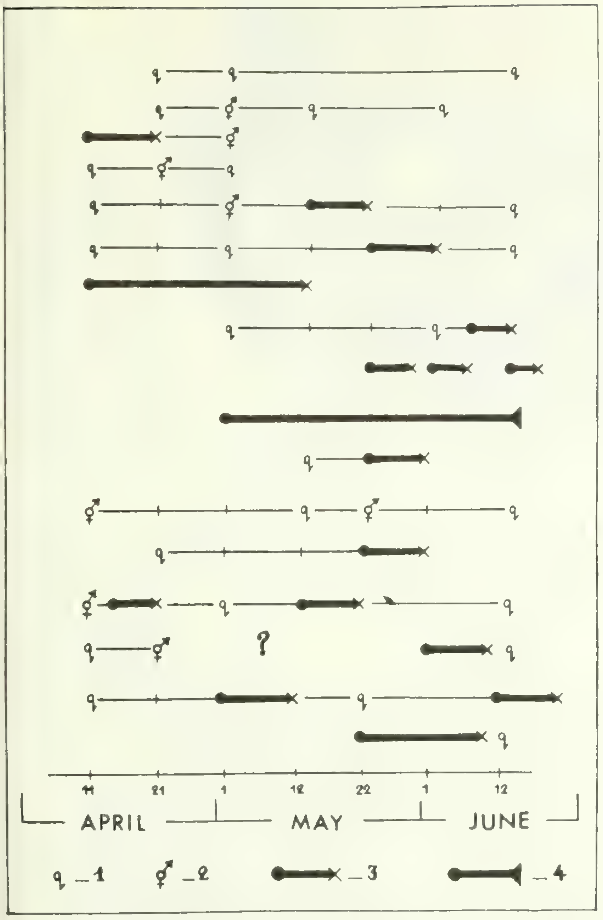

Figure 17.--Nesting status of 17 pairs of Woodpigeons near Wrocław, Poland. Symbols mean: 1--cooing male, 2--pair showing breeding behavior, 3--date of discovery of nest and period it remained active, 4--successful nest. From Tomiałojć (1974).

other methods; I simply question their practicality as a census method under normal circumstances. There are, of course, exceptional cases where populations of an individual songbird species can be determined by a thorough search for nests--but this normally requires a prohibitive amount of field work. For many canopy species it would be nearly impossible to find all the nests even with a large crew of observers.

Species Studies

When interest relates primarily to a single species or a small group of species, considerable time may be saved by a knowledge of the habits of the particular species. For the Scarlet Tanager, for instance, there is a very short period just at dawn when singing reaches a high peak. By scheduling trips to include this critical period and by moving

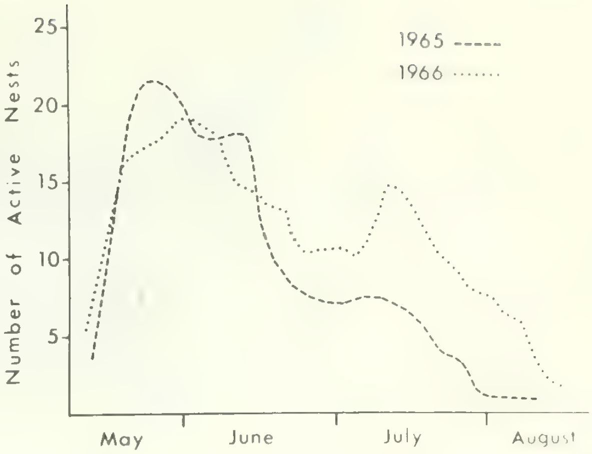

Figure 18.--Three point floating averages for the daily number of active Wood Thrush nests in a 14.4 ha woodlot in Delaware, 1965-1966. From Longcore and Jones (1969).

rapidly through the area while the birds are at their peak of song, the total amount of field time can be reduced.

Tape Recordings

For many species, playback of tape recordings can be used to induce song from silent territorial males. The technique may increase census accuracy, especially for species with low song activity, with a minimal expenditure of time. Also, the technique can be used to determine territorial boundaries. Indiscriminate use of tape recordings on repeated visits during the breeding season, however, can bias one's results because birds may alter their habits or their territorial boundaries if they believe a competing member of the same species is holding territory nearby.

WINTER SEASON TECHNIQUES

Winter Bird-Population Study

In 1948 the National Audubon Society inaugurated an annual Winter Bird-Population Study, which is published in American Birds. The purpose of this study is to obtain an estimate of the average number of birds using a particular habitat. Many observers use the same plot in which they have conducted a Breeding Bird Census by spot-mapping. Most plots range in size from 6 to 20 ha. The plots are visited from 6 to 10 times in mid-winter and the totals for each species are averaged. As in the Breeding Bird Census, the results are expressed in terms of birds per

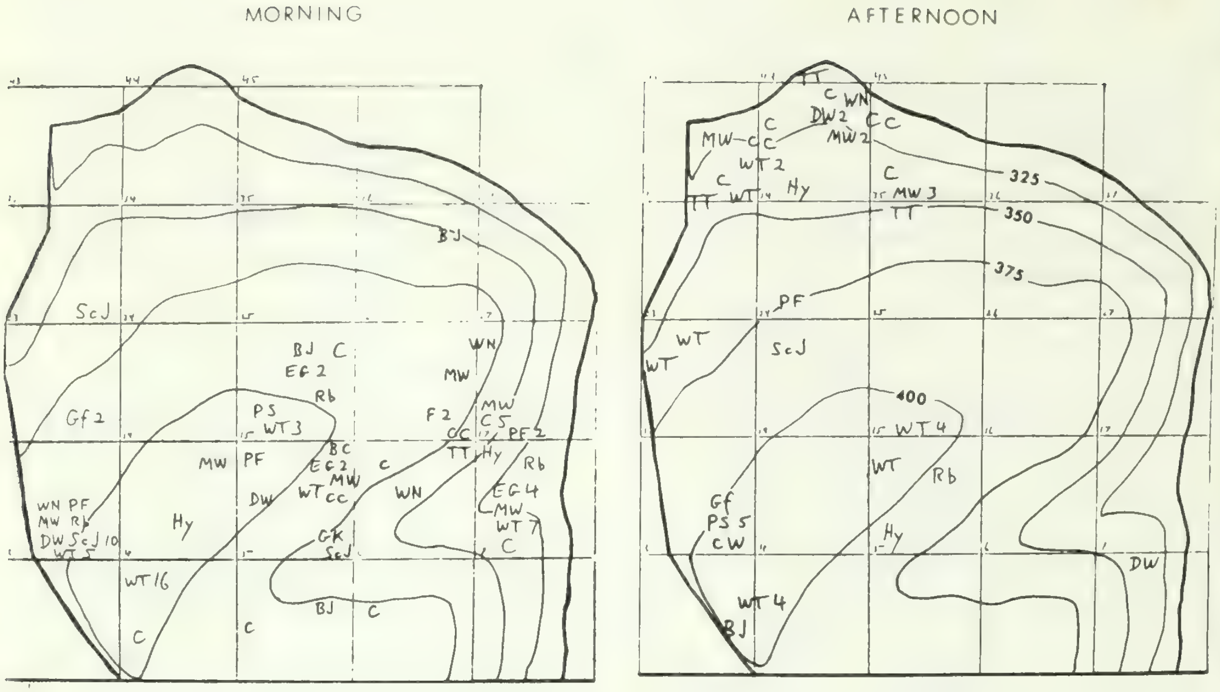

Figure 19.--Comparison of morning (left) and afternoon distribution of birds in an upland deciduous forest in Howard County, Maryland, 22 January 1978. On cold days in winter, birds tend to be attracted to sunny exposures. Squares are 250 feet on each side; elevations are in feet.

square kilometer and birds per 100 acres. Several visits per winter are necessary because populations and even the species present in a given plot vary from day to day and from morning to afternoon. Finches, robins, and waxwings for example, often range over many square kilometers in the course of two or three days. Many other species are loosely attached to mixed flocks, which may range widely, in and out of a study plot. Such flocks tend, especially on cold days, to favor sunny exposures (fig. 19), to concentrate in the better feeding sites, and to avoid windy areas.

Even when plots are covered during the best weather conditions, results must still be considered as minimum population estimates because rarely is it possible to find all the birds that are present within the plot at any given time--especially in a forest habitat.

Difficulties not withstanding, the method does give an opportunity to compare populations of different habitats and, to a lesser degree, to follow population trends over a period of years. Webster (1966) analyzed the results of 248 winter studies in forest habitats and 25 studies in grasslands. By plotting species richness against population density he found that southern pine forests mixed with oaks or gums tended to have a higher species richness than did other eastern forests.

This method can be used effectively to obtain indices of winter use. I should stress, however, that winter bird populations vary enormously from year to year at any one place, so it is highly desirable to conduct a winter population study for at least 2 years. A critique of this method (Robbins 1972) showed that in forest habitats 6 trips were sufficient to obtain a stable minimum estimate of the total wintering bird population, but that at least 8 or 10 trips were required to obtain such estimates for individual species.

Christmas Bird Count

The Christmas Bird Count (CBC), sponsored by the National Audubon Society since 1900 and published annually in American Birds, is the best known and probably the most used source of information on geographical distribution of nongame birds in winter.

Figure 20.--Winter distribution and relative abundance of Red-tailed Hawk in 1972. From Bystrak (1974). Compare with figure 8, bearing in mind the difference in scales of abundance.

As many as 1,275 circles, 15 miles in diameter, are covered annually in North America. Observers keep a record of party-hours and party-miles in the field, and estimate the time spent in each major habitat.

Maps showing the distribution and relative abundance of 143 species, based on Christmas Bird Counts (fig. 20), were compiled by Bystrak (1974) and similar maps for a few dozen other species have been published from time to time in American Birds. These maps are sufficiently detailed that likelihood of occurrence of these analyzed species in any particular forest area in the Southeast could be estimated on the basis of availability of suitable habitat.

Christmas Count data also can be used for comparison of winter bird populations of any particular forest area with those of published studies in the same or nearby counties.

Winter Bird Survey

In an effort to design a more standardized method of assessing bird populations in winter, the Maryland Ornithological Society undertook a Winter Bird Survey in central Maryland for 5 consecutive years, 1970-1974. Preliminary tests showed that the Breeding Bird Survey method would not be practical because of heavy traffic problems on many roads in the first few hours after sunrise in winter and because lack of singing made it difficult to detect birds that could not be seen from the roadside (Robbins 1970).

The method adopted, therefore, involved transects of 8 km (5 miles) that were covered on foot in the first 4 hours after sunrise. One route was established at the center of each 7 1/2-minute Geological Survey map in central Maryland, giving an 11 x 14 km grid. An effort was made to lay out each route in the form of a square, 2 km on each side. Many routes were forced to depart from the square shape because of streams, ponds, buildings, high fences, and other obstacles; but despite changes in shape, the total length of 8 km was maintained. By timing their walking speed for the first quarter of the route, observers were able to arrive back at the starting point within a very few minutes of the prescribed 4-hour period. A separate count was kept for each hour, and birds identified at a distance greater than one-quarter mile were recorded in a separate column on the form.

Most of the 46 routes were covered each year, and because coverage was standardized, the population changes from year to year could be analyzed statistically. Significant changes were found for many species. The Winter Bird Survey data also were used to map the relative abundance of various species throughout central Maryland (Bystrak and Robbins 1972, Robbins and Bystrak 1974).

Comparison with Christmas Bird Count Data

There were four CBC circles within the area covered by the Winter Bird Survey. This permitted direct comparison of the results of the two methods. Although published CBC's, from their inception in 1900, have included the number of hours of field coverage, this coverage varies enormously among areas and

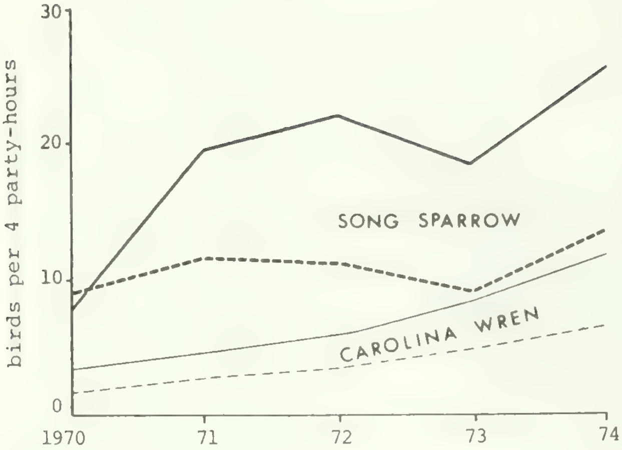

Figure 21.--Comparison of bird population trends as shown by Winter Bird Survey (solid lines) and Christmas Bird Count (dashed lines).

from year to year. Because of the changes in coverage, changes in observers, and lack of control over weather conditions, the CBC data have been believed too crude for application of statistical analysis. Comparison with the Winter Bird Survey data, however, revealed that the CBC's show year-to-year trends very similar to those detected in the same geographic area by the Winter Bird Survey (fig. 21). Species commonly seen along roadsides and at feeding stations were recorded in larger numbers (per 4 hours of field work) on the CBC, while species typical of fields and forests were found in larger numbers on the Winter Bird Survey. Nevertheless, the year-to-year trends were similar, suggesting that, despite the disadvantage of uncontrolled variables, CBC's can be used in a general way to show population changes. The advantages of the CBC data are the large number of years represented and the large sample of observations each year: as many as 200-300 party-hours concentrated in a small area.

European Winter Transects

The Winter Bird Survey method was tested simultaneously in the British Isles and in Maryland. The British had some reservations about the success of their program, largely because of high variability caused by wandering Lapwings, a plover that occurs in large flocks and moves gradually from east to west across the British Isles as the winter progresses. Hence, the British study was discontinued and the results were not published.

A series of walking transects, varying from 2 to 30 km in length, was initiated in Finland in 1956. About 6500 km of Finnish landscape are now hiked each winter (Sammalisto 1974).

In Sweden the winter transects consist of twenty 5-minute stops (Källander 1978). Each transect is covered monthly from November through March with the same stops, same time, and same observer each year. The data from both Finland and Sweden are entered on punch cards and analyzed statistically to show national trends in winter populations.

TECHNIQUES FOR OTHER SEASONS

Transects

The transect method has been the one most frequently used to monitor year-around changes in bird populations. Admittedly, its accuracy varies with season of the year depending upon activity of the birds and visibility across the various habitats. Width of the transect strips has varied with the several authors, and no attempt has been made so far to standardize strip width among investigators in different countries.

Most transect workers have walked alone, but Stewart et al. (1952) in a 2-year study at the Patuxent Research Refuge in Maryland, used 3 observers walking parallel lines 100 m apart to sample a strip 300 m wide and 4.2 km long (about 123 ha). During the breeding season the observers worked strictly from the census lines, but at other seasons they departed as far as 50 m from the census lines whenever necessary to get better counts of flocking birds. Two observers often worked together on the same flock to obtain the best estimate of flock size and composition. It was believed that by having three observers the errors in estimating lateral distances were minimized as was the likelihood of obtaining poor estimates of flocking species.

Transect Sampling in North Wales

To determine bird use on nine national nature reserves in the county of Merioneth, North Wales, the Nature Conservancy established a program under which 50 km of heather and 50 km of grassland would be censused by transects during each month of the year (Jones, 1974). Each transect belt was 200 m wide and the right angle distance to each bird from the transect line was estimated. This long-term study began in 1968 and was to continue until the sample for each month in each major habitat reached 50 km. Jones used the method of Gates et al. (1968) and Emlen (1971) to convert transect data into an estimate of the total population, using a coefficient of detectability. This method is

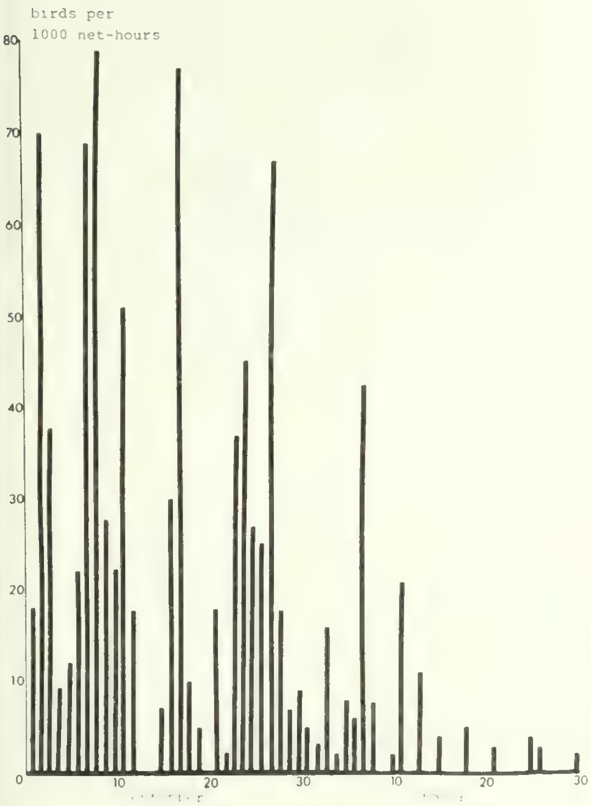

Figure 22.--Daily bandings (birds per 1000 net-hours) of American Redstart at Ocean City, Maryland, September and October 1966.

more likely to be successful in open habitats such as those used by Jones than in heavily forested habitats where many birds at close range can escape detection.

Bird Banding

When banding is done consistently throughout a migration season, it provides quantitative data on populations of those species that are readily trapped under the conditions that prevail at the particular banding site. The records of the major bird observatories in North America (and also of those in Europe) provide an excellent sampling of a wide variety of species and have an additional advantage in that reliable age ratios for each species for the particular locality are obtained. As in any study during the migration periods, weather has a major effect on daily counts of migrating birds (fig. 22) and also causes problems such as local concentrations or overflights, any of which may reach major proportions and make it frustrating to attempt statistical analysis of data from a single year. Over a period of years, however, a good statistical sample can be obtained. Attempts to monitor migratory populations by banding are most successful where shorelines, mountain ridges, river valleys, oases, or other topographic or vegetational features help to concentrate the migrating birds.

One important advantage of monitoring migrants by trapping and banding is that mist nets are especially effective for birds of heavy underbrush and dense thickets; such birds are rarely seen and are almost impossible to detect when they are not singing. While mist nets are highly effective for capturing migrants, it must be born in mind that they cannot be used effectively on a daily basis during breeding or winter seasons because the birds rapidly become familiar with the placement of the nets and learn to avoid them. It should also be emphasized that use of mist nets is a specialized technique that requires special Federal and State permits, which are granted only to workers with considerable training and experience.

DISCUSSION

The above commentary gives the research biologist a considerable selection of methods from which to choose. Each method has severe limitations if one's objective is to achieve an accurate measurement of the absolute size of bird populations, especially if abundance of one species must be compared directly with abundance of other species.

Attempts to measure statistical error of bird census results will be frustrated by almost insurmountable biases associated with: (1) daily or even hourly changes in the populations being sampled; (2) daily changes in behavior such as nesting activities and singing (Weber and Theberge 1977); (3) effects of different weather conditions on audibility, visibility, and behavior of the birds and of the observers; (4) differences, even slight ones, in time of day as it affects bird activity (Robbins and Van Velzen 1970); (5) differences among observers; (6) differences in attentiveness of even a single observer; (7) differences such as walking speed (Colquhoun 1940) or the exact route the observer follows from day to day; and (8) lack of information on the absolute numbers being estimated.

Design of the procedures and selection of experienced personnel to conduct the field work and analyze the results are no less important than the selection of census methods. The objectives of the study and the time frame in which it must be completed will dictate

which method, or more likely, which combination of methods, will be most efficient. Attempts should be made to minimize effects of as many as possible of the inherent variables. The bulk of the field work should be concentrated in the early morning when activity is greatest and most consistent. Except for studies of migration itself, the migration periods should be avoided and work should center on the peak of the nesting period or the middle of winter. Census work should be standardized with relation to sunrise (or sunset). Minimum weather standards for field work should be established. Observers with considerable experience in census work should be chosen, bearing in mind that most of the censusing of forest birds is done by ear. Most biologists, whatever their level of general knowledge, lack the specialized skills required. Observers should be calibrated, rotated among the various tracts being compared, and for studies lasting more than 1 year, enlisted for the duration of the study.

It is desirable to assess the accuracy of the method or methods being used. This is frequently best accomplished by a more intensive study of two or more of the sample plots.

CONCLUSIONS AND RECOMMENDATIONS

1. Although bird censuses are imprecise, they have considerable value in a relative sense.
2. If the techniques are designed so as to minimize effects of variables that can be controlled, valid comparisons may be made among bird populations of two or more plots.
3. The spot-mapping method is recommended for greatest precision, and when a study is to be repeated over a period of years. Carefully standardized transects or point counts are most effective when many plots are being compared, and relative rather than absolute numbers will suffice.
4. Any method selected may be calibrated by a more thorough coverage of sample plots by the same or another method.
5. Demand for data on bird populations and species composition in specific habitats is increasing rapidly. Therefore, the results of census work should be published or at least made available through data banks or other means.

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Thursday Morning, January 26

Research Plans

Moderator: Michael R. Lennartz
Southeastern Forest Experiment Station

A Representative Sample of Ongoing and Planned Nongame Bird Research in the Southeastern Region United States

Robert L. Curtis, Jr.[1/]

Abstract.--This paper highlights the ongoing and planned nongame bird research efforts in the Southeastern Region of the United States. Over 40 percent of all sampled ongoing research is directed toward threatened and endangered species. The U.S. Forest Service and various southern universities are the agencies most heavily involved in nongame bird research. A comparison of ongoing research with previously defined nongame bird information needs is presented.

INTRODUCTION

Two and one-half years have passed since many of us met at the Symposium on Management of Forest and Range Habitats for Nongame Birds in Tucson, Arizona.

If a consensus of opinion regarding information needs was reached at that symposium it was perhaps that management of nongame birds and their habitats is a relatively new resource issue and that there is a serious scarcity of information available to land managers and resource decision makers for formulating and assessing management programs.

Michael Lennartz and Ardell Bjugstad, who highlighted information and research needs for nongame bird habitat management, stressed that any discussion of management information on research needs must follow some understanding of what management is or what management should attempt to achieve.

I doubt that we were able then, or could now, agree on this point. However, two philosophies for management and research for nongame birds tended to recur throughout that symposium. These are:

1. Native vegetative communities or habitat types must be protected and enhanced in order to protect and perpetuate all representative native avian communities, and
2. Endangered and threatened species and their habitats must be protected and perpetuated.

If we accept these as broad management guidelines, then the question becomes, what information do land managers need to meet them? Is this information being procured through our ongoing research programs?

The first portion of this question has been answered in a large part by Lennartz and Bjugstad (1975) with help from their fellow professionals at Tucson.

The focus of this presentation will hopefully shed some light on the second portion of the question. Just how far have we come since that first nongame bird symposium in 1975? Have we as a professional working group been successful in establishing a nongame bird research direction, and are we addressing the priority information needs which were identified two and one-half years ago?

METHODS

In this presentation, I have attempted to assemble a representative sample of ongoing nongame bird research efforts in the southeastern states. Attempts were made to sample a diverse selection of both Federal and state agencies having different research and management mandates. Colleges and universities, as well as private conservation organizations, were also queried. The entire geographic range of the southeastern region was covered, extending from the Atlantic coast to Texas, Oklahoma, Missouri, and Arkansas.

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A total of 35 questionnaires was distributed to nongame bird researchers in this region. Twenty-six investigators responded to my inquiry and provided me with a listing and description of 84 ongoing nongame bird research projects which form the substance of my presentation. A summary of vital information regarding each project is included in the Appendix.

To facilitate discussion and presentation, I have sorted the research projects into eight categories based upon the title, objectives, species or group of species, and, in some cases, study methodology. Although some projects could, of course, fit into more than one category, my sorting approach does provide an organized framework for discussion, presentation, and comparison.

The research categories include:

1. Threatened and Endangered Species Ecology
2. Effects of Forest Management Practices
3. Species Ecology
4. Avian-Forest Habitat Associations
5. Structural Niche Determinations
6. Surface Mining Impacts on Avifauna
7. Electric Transmission Line Impacts on Avifauna
8. Raptor Investigations

PREVIOUSLY DEFINED INFORMATION NEEDS

Before discussing each of the research categories and the current research programs I will quickly summarize the priority information needs identified by Lennartz and Bjugstad (Ibid.). These were:

Information Needs

1. Information allowing managers to assess the impacts of management systems on nongame birds and their habitats.

2. Greater quantitative explanations of the distributive niche selection of avian species and communities through accelerated use of multivariate analysis techniques.

3. A characterization of the extent, distribution, and condition of the avian resource base for use in avian management planning in conjunction with other resource outputs--e.g., timber, forage, and water.

4. Information on avian community/forest community associations.

5. Accelerated research emphasis on climax or mature vegetative communities and microhabitat components--e.g., snags and cavity trees.

6. Information concerning habitat requirements and management for endangered and threatened species. This latter need was ranked, almost without exception, as the highest priority of both managers and researchers.

ONGOING NONGAME BIRD RESEARCH - AN OVERVIEW

With the above information needs in mind let me now provide an overview of the ongoing nongame bird research program.

Figure 1 presents the results of my regionwide inquiries and discussions with nongame bird investigators. The figure provides a category breakdown of all 84 research projects, and the percentage contribution of each category to overall regional research activities.

Two categories of research, threatened and endangered species investigations, and studies into the effects of forest management practices on avifauna, account for 49 of the 84 projects or 58 percent of the sampled research activity. The lion's share of this research effort belongs to threatened and endangered species, which account for 37 of the 84 studies for an impressive 44 percent of the sampled ongoing research.

The third most active research category, investigations of species ecology, is represented by 11 projects accounting for 13 percent of all research activity. Studies on avian-forest habitat associations account for 11 percent. The other five categories each account for less than 10 percent of all research.

RESEARCH CATEGORIES

Threatened and Endangered Species

Clearly, an impressive impetus has rapidly developed for the endangered species research program. The high level of support which this program now enjoys is a result of an awakened public concern and interest as well as a better understanding of man's role and moral responsibility regarding species extinction.

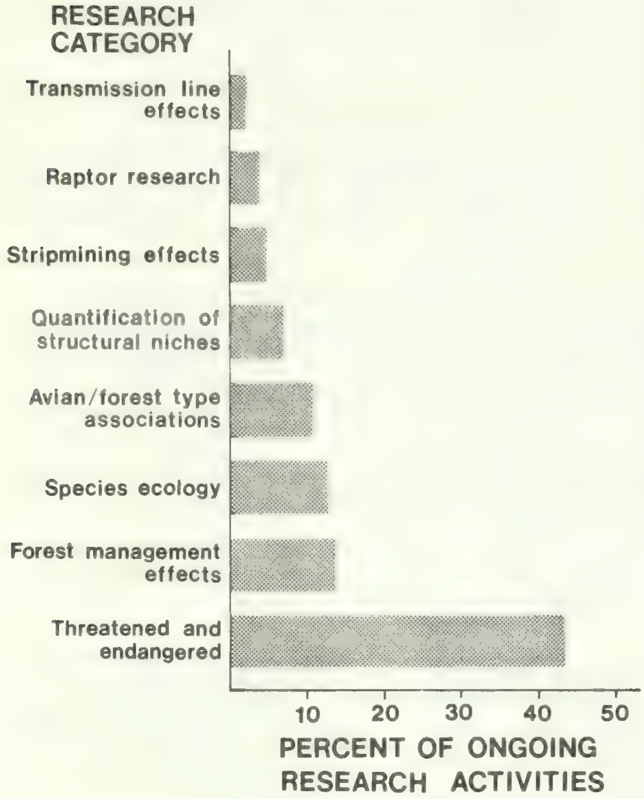

Figure 1.--Percent composition by category for sampled ongoing nongame avian research in the Southeastern Region as determined by a survey conducted in October 1977.

Conceptually the information needs for endangered species are no different than for any other avian species. We need the same information regarding population, distribution, resource utilization, and habitat selection. But the needs are urgent; the time frame is critical.

The endangered species experience graphically illustrates that the future of wildlife in America is dependent upon much more than just our understanding of wildlife ecology. Law, economics, and politics will have increasing impact on wildlife populations and programs. For example, as Lennartz and Bjugstad (Ibid.) point out, the plight of species headed for extinction has become one of our most publicized and emotional contemporary wildlife problems. This interest, whether emotional or pragmatic, has been translated into active programs through Federal legislation (Endangered Species Act of 1973). Admittedly, not all of the support intended in the Act has materialized, but a firm foundation has been established.

The Endangered Species Act also requires that all Federal or Federally funded land management programs protect endangered species and their habitat (Ibid.). To do so requires a quantum jump in available information. In response to Endangered Species Act requirements for increased protection and management, we find a substantial portion (44 percent) of southeastern nongame bird research centered about endangered species problems.

From figure 2, it is readily apparent that the Red-cockaded Woodpecker is the endangered species receiving most of our research attention. Approximately one-third of the research projects directed toward the Red-cockaded Woodpecker are being sponsored by the U.S. Forest Service, Southeastern Forest Experiment Station (Lennartz and Hooper, 1976). The objective of their research is to determine the essential habitat elements selected by Red-cockaded Woodpeckers throughout their home range, so that forest managers can assess, or predict, the effects of alternative forest management strategies on woodpecker populations.

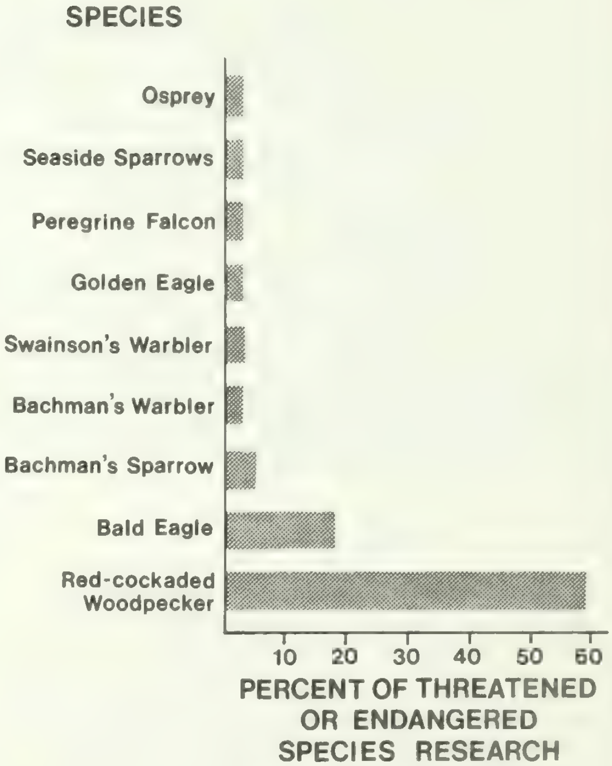

Figure 2.--Percent composition by species for sampled ongoing threatened and endangered species research in the Southeastern Region as determined by a survey conducted in October 1977.

The U.S. Forest Service's interest is understandable in light of Chamberlain's (1974) report that ". . . the National Forests of the Southern Region are extremely important to the Red-cockaded Woodpecker. In several states it is likely that a major portion of the state population occurs on National Forest lands."

The states of Florida, Arkansas, and South Carolina also have active projects on the Red-cockaded Woodpecker. These efforts are being funded primarily through the U.S. Fish and Wildlife Service, Endangered Species Act Federal Aid Program.

Other species currently subjects of research include Bachman's Sparrow, Swainson's Warbler, Bachman's Warbler, Southern Bald Eagle, Seaside Sparrow, and the Peregrine Falcon (fig. 2).

Forest Management Practices

It is probably true, as Hamilton and Noble (1975) point out, that most avian management on our forest lands will be in conjunction with other management objectives such as timber, recreation, forage, or water. The demands for timber will have increased greatly by the year 2000, yet, if current trends continue, there will likely be less acreage available for commercial timber production. Obviously to produce enough wood and wood byproducts to satisfy demands requires more intensive management effort on those lands which will remain in forest production.

Consequently, in managing for, and in consideration of, the avifaunal resources on forest lands, especially public lands, the ability of the manager to attain true multiple use will be strained to the utmost (Hamilton and Noble, 1975).

Probably one of the most difficult tasks facing the manager will be to determine the avian management objectives for an area. This will be even more difficult as other resource objectives enter into the planning process.

To ensure that avian management planning is no less sophisticated than planning for the primary resource outputs, managers must have information regarding the effects of the many silvicultural alternatives and various cultural techniques possible. Understandably, Lennartz and Bjugstad (1975) point to this as one of the most pressing information needs of managers.

My inquiries revealed that research efforts into the effects of forest management practices on avifaunal resources is the second most active category of investigation (fig. 1). Twelve of the 84 projects reported were within this category which represents 14 percent of sampled regional research.

A variety of forest cutting techniques, cultural systems, and forest management practices are currently being investigated (Appendix). Specifically, among them are:

1. The benefit of woodland openings to avifauna.

2. Effects of various type conversions and monoculture forest systems.

3. Effects of clearcutting, herbicide treatments, selection cutting, and various combinations of the three on avifauna.

4. Effects of cable logging and whole tree chipping.

5. The role of various microhabitat elements such as snags and nesting cavities in avifaunal habitat.

Of the five primary areas listed above, the greatest amount of research is being directed toward the effects on avifaunal resources of various cutting systems, i.e., clearcutting, clearcut/herbicide, selection cutting, and whole-tree chipping.

The general pattern of impacts directed on avian habitats and communities by these intensive timber management activities have been described by several authors (Thomas et al., 1975; Hamilton and Noble, 1975; Conner et al., 1975). Unfortunately, quantitative investigation of a more precise nature is almost totally lacking. Research which could provide indices of quantitative avian use of forest habitats under various management systems with special reference to habitat selection and resource is definitely needed. Many of the projects listed in the forest management practices category will provide this information.

The U.S. Forest Service is the leader in this research effort by being either directly involved or lending support services to 10 of the 12 projects listed under this category of research.

Species Ecology

Excluding threatened and endangered species work, much of the current research can be loosely described as avian community

ecology. I have included the species ecology category of research to capture those projects relating to the life history of a species or closely related groups of species.

Good quantitative field data on many facets of avian life cycles are either lacking, fragmentary, or comprised of small sample sizes. I would stress that information on both the individual species and the avian community is essential. As Balda (1975) has pointed out, neither autecological nor synecological studies alone can adequately describe the patterns of habitat selection and resource utilization.

Of the 84 projects, 11 were included in the species ecology category. This represents 13 percent of all research activities sampled (fig. 1). Included in this category are projects relating to nesting ecology, foraging ecology, range extensions, cavity nest predation, and parasite ecology (Appendix).

Avian-Forest Habitat Associations

Zeedyk and Evans (1975) suggest that more emphasis should be directed toward developing, with the necessary supporting research, silviculturally oriented avian management alternatives and guidelines. Among other things, coordinated monitoring of breeding bird populations would be an integral part of the forest inventory. Thus bird population trends could be correlated with shifting forest land-use trends. Lennartz and Bjugstad (1975) point out that foresters utilize various continuing inventory systems to assess the timber crop, and that as we become more knowledgeable about which birds are associated with which forest types, it may be possible to incorporate avian habitat assessments into existing forest inventory systems.

Nine of the 84 projects reported were classified under the category of avian-forest habitat associations studies. This represents 11 percent of the current research work (fig. 1). Although projects under this category differ greatly in their regional scope, study methodology, and specific objectives, they all attempt to identify bird communities associated with primary forest types and successional stages in either a portion of or the entire Southeast.

The U.S. Forest Service cooperative study with Clemson University (Gathreaux, 1977) plans a rather broad regional attempt at quantifying avian communities with forest associations. These associations and the resulting avian habitat assessment system will be developed primarily from existing literature sources with some field validation (Lennartz, personal communication). The feasibility of such habitat assessment systems is in direct proportion to the amount of information available regarding avian community/plant community associations and quantified parameters of habitat suitability (Lennartz and Bjugstad, 1975). Fulfilling this need is one of the tasks being done by the Southern Forest Experiment Station in Nacogdoches, Texas, with the objective of elucidating the effects of stand structure on bird population in two limited but specific forest types, in this case the pine and pine-hardwood forests of east Texas (Dicksen, 1977).

Studies such as these, as well as the others in this category (Appendix), may provide us with the basis for characterizing, on a regional basis, the distribution and extent of our avian resource. This type of information is basic, indeed essential, to intelligent land management planning.

Quantification of Structural Niches

In my sample, this category accounts for 6 percent of the current research activity (fig. 1). Five research projects were placed in this category. I should point out that the title of this category stresses quantitative efforts, particularly those utilizing multivariate analysis, as these methods provide the means to most efficiently analyze vast amounts of acquired information.

Originally, the niche concept was used to summarize the general characteristics of a species' natural history. This broad definition has since been redefined to describe functional relationships (Elton, 1927), interspecific interactions, and feeding and nesting preferences (Conner and Adkisson, 1976). Several studies have illustrated that both the structural and functional aspects of vegetation are important in avian habitat selection (Wiens, 1969; Anderson and Shugart, 1974). McArthur et al. (1962) by correlating bird species diversity with foliage height diversity predicted the presence of a bird species from measurements of the amounts of foliage in three horizontal layers. More recently, researchers have used both univariate and multivariate analysis in approaching the determination of a species niche (Cody, 1968; James, 1971; Shugart and Patten, 1972).

Ideally, niche information can be used by wildlife managers as a tool for the

preservation of wildlife habitat. A good understanding of species niche requirements is especially important where timber production and wildlife must coexist (Bunnell et al., 1977). An analysis of habitat characteristics comprising a niche is a prerequisite to rational application of land management systems.

Surface Mining and Reclamation Effects on Avifauna

Approximately 5 percent of ongoing avifaunal research is in the area of strip mine and reclamation impacts on avifauna (fig. 1). This category accounts for four of the 84 projects reported. There is a paucity of information regarding both the initial impacts of surface mining and the effects of various reclamation techniques on avifaunal resources. To date only two breeding bird studies have been completed on contour surface mines (Yahner, 1973; Garton, 1974). Information regarding the avifaunal resources on area surface mines is almost as sparse, with only three studies having been located (Brewer, 1958; Karr, 1968; Terrel and French, 1975). A further complication is that most previous research has been conducted on either orphan mine lands or on recently reclaimed conventionally mined areas.

With the increased emphasis on coal as a primary energy resource of the future, both contour and area surface mining activities will be accelerated in our southern coal production states of Virginia, Maryland, Kentucky, West Virginia, Tennessee, and Alabama. In all of these, surface mining has been a major source of habitat disruption.

Prior to reclamation laws, thousands of acres were simply stripped and abandoned. The best methodologies for reclaiming these abandoned lands for the benefit of avifaunal resources as well as other types of wildlife are poorly understood at this time. We know which birds live in each general habitat type, but quantifying the relationships so that specific reclamation models can be constructed has not been adequately achieved (Samuel and Whitmore, 1976). Recent passage of the new Federal strip mine legislation, with its back-to-contour provision, adds a new unexplored dimension to the reclamation problem.

A knowledge of the avifaunal utilization of surface mined areas is an important element in evaluating the management of reclaimed areas. Breeding bird population parameters may be the best indicators of the relative health or degree of recovery of a mined area and are important factors in determining the degree of success of a reclamation plan.

Expanded quantitative studies on avian use of surface mine habitats are a basic prerequisite to sophisticated surface mine reclamation planning. Until this information is available, only rudimentary management will be possible.

Raptor Research

To date, few studies have been addressed specifically to the subject of raptor management or conservation. While information of importance to raptor conservation has been gained through studies aimed at other goals, progress toward comprehensive understanding of what is needed to sustain raptor populations is still in the formative stages. As yet, most comprehensive management efforts on raptors have been limited to threatened or endangered species (Snyder and Snyder, 1975).

My sample indicates that this situation has not changed a great deal within the last several years. Excluding threatened or endangered species, I have listed three of the 84 projects in the raptor research category. These three projects account for 4 percent of the ongoing research reported (fig. 1).

Additionally, there are 10 projects dealing with threatened and endangered raptors listed under the endangered species category. Much of this work, particularly on the Bald Eagle, is directed toward nesting surveys, determination of population status, and distribution patterns.

While the current emphasis on methods to save the threatened or endangered raptors is probably appropriate, in the long run we should hope for a broader program--one which strives to ensure that those species still in relatively good shape do not end up on the endangered list.

Electric Transmission Line Effects on Avifauna

This final category includes two projects accounting for slightly more than 2 percent of the ongoing research. Clearly, transmission line impacts have not been considered a priority research area within the last several years.

There are two distinct types of impacts associated with electric transmission lines. The first type of impact is that associated with the actual transmission line clearing, construction, and subsequent maintenance of vegetation. These impacts are most predominant where previously forested habitats are converted to relatively narrow corridors of periodically maintained shrub vegetation. The second type of impact occurs as birds strike the electric transmission conductors and support towers.

Currently the U.S. Fish and Wildlife Service and the Tennessee Valley Authority are the only agencies reporting research on transmission line impacts. The Tennessee Valley Authority research contract with the University of Georgia addresses the first type of impact, i.e., habitat loss or vegetative type conversions through construction and maintenance operations.

Currently very little is understood regarding the second problem--birds striking transmission conductors and support towers. As evidence of increasing concern for this problem, a workshop is being organized by the Oak Ridge (Tennessee) Associated Universities in cooperation with the U.S. Fish and Wildlife Service to address this very question. Workshop objectives are to determine the scope of the problem of birds striking transmission lines and to produce guidelines for management and research on this subject.

PROGRESS TOWARD PREVIOUSLY DEFINED INFORMATION NEEDS

Having presented an overview of ongoing and planned avian research, I would like to compare the ongoing programs and the previously defined information needs (Table 1). The information needs listed are the six most critical areas requiring attention as defined by Lennartz and Bjugstad (1975) and listed earlier in the presentation. By reviewing each of the 84 project titles and objectives I have made an admittedly subjective determination regarding the information needs they fulfill. Several projects were judged to satisfy more than one information need. Therefore, the Number of Projects and Percent columns will total more than 84 projects and 100 percent, respectively.

The information needs in Table 1 are not ranked in any order of urgency with the exception that endangered species research was given the highest priority (Lennartz and Bjugstad, 1975).

It is apparent that endangered species research is receiving a great deal of attention. Some may argue that endangered species are demanding too much attention at the expense of other wildlife problems. The fact remains that it has been ranked as our number one research priority and the degree of emphasis that it is receiving is probably justified. The current emphasis on endangered species research is, however, heavily weighted toward the Red-cockaded Woodpecker (fig. 2).

Table 1 also indicates that emphasis is being given to the areas of (1) avian resource distribution, (2) impacts of forest management, and (3) climax communities and associated microhabitat elements. The survey revealed a lesser degree of activity toward the final two information needs: avian/forest habitat association and avian niche selection.

Eleven percent of the current research activity is directed toward identification of avian/forest habitat associations (Table 1). The concept of incorporating avian habitat assessments into existing

Table 1.--Previously defined nongame avian information needs and the number and percent of sampled ongoing projects which contribute to each as determined by a survey conducted in October 1977.

Information Needs[1/]	Ongoing or Planned Research	
	Number of Projects	Percent
Endangered Species	37	44
Impacts of Forest Management	12	14
Niche Selection	6	7
Distribution of Avian Resources	22	26
Avian/Forest Habitat Associations	9	11
Climax Communities and Associated Microhabitat Elements	17	20

1/ Lennartz and Bjugstad, 1975

forest inventory systems is fairly new. As greater precision is required in assessing trends and conditions of the avian resource, development of a practical habitat assessment system for all forest types and successional stages should receive accelerated emphasis.

Seven percent of the research activity is being directed to use of multivariate analysis for quantitative explanation of the vegetative structure of the avian habitat niche. Cody (1968), James (1971), and Shugart and Patten (1972), utilizing multivariate techniques, have identified important habitat factors of different avian species. Nevertheless, the application of multivariate statistical techniques to nongame bird habitat and its management remains at a minimum (Mann, 1977).

Multivariate statistical techniques can be exceptionally useful in optimizing management strategies for avian resources and for identifying potential impacts of change in management policies (Shugart et al., 1975). Both new and experienced researchers should be encouraged to become familiar with the descriptive power and utility of these techniques.

AGENCY INVOLVEMENT IN RESEARCH

As evidenced by Figure 3, almost one-half (48 percent) of the ongoing research is being conducted by university researchers, frequently masters' degree or doctoral candidates. Universities were found to be actively involved in all eight categories of avian nongame research.

The U.S. Forest Service is involved in 26 percent of all sampled research activities; over half of this 26 percent is being handled by the Service's own biologists at various forest experiment stations in the southern, southeastern, and north central regions. The remainder are cooperative projects between the U.S. Forest Service and various universities.

The survey indicates that the U.S. Forest Service is heavily involved in two of the eight research categories: threatened and endangered species, and effects of forest management practices on avifauna.

Our National Forest wildlife habitat programs in the past have sought to maximize the production of game species and research has been directed toward these ends. However, one of the greatest influences stimulating the U.S. Forest Service's new accelerated research in the area of endangered avian species has been

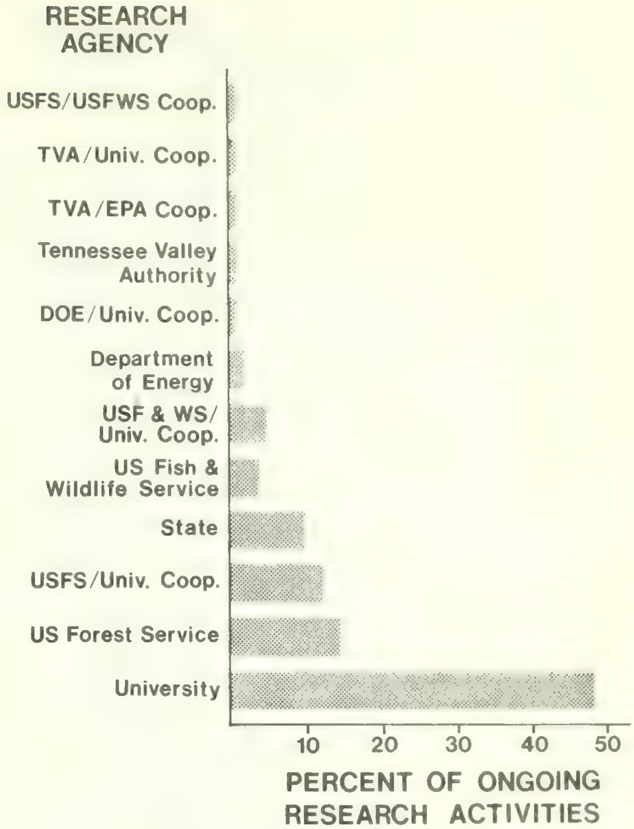

Figure 3.--Percent composition of agencies active in sampled ongoing nongame avian research in the Southeastern Region as determined by a survey conducted in October 1977.

the responsibility placed upon Federal agencies by the Endangered Species Act of 1973. In addition, the Service's mandate and policy to consider multiple resource management and use of all wildlife species, coupled with exploding public interest in nongame wildlife, have encouraged greater research emphasis on the unknowns of avian nongame management.

State agencies are engaged in approximately 10 percent of the sampled research activity. Their involvement is primarily with threatened and endangered species, with funds being provided by the Endangered Species Act of 1973 and administered through the U.S. Fish and Wildlife Service.

The U.S. Fish and Wildlife Service alone, and in cooperation with several southern universities, accounts for 9 percent of the ongoing research. They are involved in a diverse mix of research activities including surface mine studies, electric transmission line impacts, avian-forest

habitat type associations, raptor research, and endangered species research. The U.S. Fish and Wildlife Service also conducts and maintains data files on the National Breeding Bird Survey. This survey was started in 1965 and was designed to help monitor environmental quality by measuring changes in abundance in North American breeding birds.

Research activities of the Department of Energy and university cooperators accounted for 3 percent of the sample. These research projects are administered through and directed by the Environmental Sciences Division of the Oak Ridge National Laboratory.

Tennessee Valley Authority and TVA/cooperative projects make up approximately 4 percent of ongoing research. The TVA projects relate primarily to energy production impacts on the avian resource and include research projects on surface mining impacts and effects of electric transmission lines on avian communities.

SUMMARY

Clearly, both wildlife management and research programs are having to respond to a new wildlife consitituency. This response has been a long time in coming but now seems to have gained a firm hold in what may be described as a new direction for the wildlife management profession.

While hunters still comprise 10 percent of the population, present estimates indicate that a great majority of Americans have an active interest in a broad spectrum of wildlife values other than the production of a shootable surplus. The diversity of our nongame birds provides an especially unique and challenging opportunity for resource professionals to coordinate the management of these species with other forest resource outputs. Yet, for most wildlife professionals, management of nongame birds and their habitats is a new resource issue, and a sound information base for a management program is lacking for many species. Consequently, as evidence and encouragement to you, the managers, that substantial progress is being made toward filling these information voids, I have attempted in this presentation to provide a capsule summary of our ongoing avian nongame research program in the southeastern region. I have also compared the ongoing research projects with the critical nongame bird information needs defined by Lennartz and Bjugstad (1975).

A summary of the salient points of the presentation is as follows:

1. Endangered species research accounts for 41 percent of all reported nongame avian research in the southeastern region.

2. Research on the Red-cockaded Woodpecker comprises almost 60 percent of all reported threatened or endangered species research. Approximately one-third of all Red-cockaded Woodpecker research is being sponsored by the U.S. Forest Service.

3. Research effort devoted to the effects of forest management practices on avifauna is the second most active research category, accounting for 16 percent of sampled research. The U.S. Forest Service is also the leader in this research effort, being either directly involved in or lending support services to 83 percent of the projects.

4. The development of avian-forest habitat associations constituted 11 percent of the sampled ongoing or planned research. Once knowledge of these associations is developed, monitoring of breeding birds populations can be made an integral aspect of continuing forest inventory. It may become possible to predict bird population trends associated with shifting forest land use patterns.

5. Effects of surface mining and reclamation on avifauna constitute a fairly small (5 percent) portion of ongoing research. With increased emphasis on coal as a primary energy resource of the future, surface mining activities will be vastly expanded. Habitat in six of our southeastern states (Virginia, Maryland, Kentucky, West Virginia, Tennessee, and Alabama) will be heavily impacted. Consequently, this area of avian research bears greater emphasis.

6. Aside from research on threatened and endangered species, the survey indicates that very few raptor studies (4 percent) have been initiated dealing specifically with the subject of raptor management on conservation.

7. The comparison of sampled ongoing research with information needs as defined by Lennartz and Bjugstad (1975) indicates that all six critical information voids are currently receiving research emphasis.

8. Approximately one-half (48 percent) of all ongoing avian research is being conducted by universities. The U.S. Forest Service is the second most heavily involved agency being either wholly or partially responsible for 26 percent of all sampled research activity.

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The Forest Service, U. S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

Department of Agriculture May 1979

t Service General Technical Report SE-15

FERNS of the Blue Ridge

by Arnold and Connie Krochmal

Southeastern Forest Experiment Station
Asheville, North Carolina

FERNS OF THE BLUE RIDGE

by
Arnold and Connie Krochmal

The forests and open fields of the Blue Ridge provide ideal growing onditions for a number of ferns. Since some of these are evergreen, ferns an be seen in the area during every month of the year.

Ferns are old members of the plant kingdom, and fossil ancestors are ommon in slate, shale, and coal. All ferns belong to the Pteridophytes, a roup that also includes mosses, horsetails, and quillworts. These plants do ot produce flowers or seeds; they reproduce by means of spores.

Fern spores are produced in structures called sporangia, which are orne in small clusters on the leaves or *fronds*. A cluster of sporangia is alled a *sorus* (plural *sori*). Sori appear as brown spots along the veins, at he ends of veins, and at the margins of fertile fronds, or *sporophyls*. The etails of the structure of these bodies can be seen with a simple hand lens. ome ferns have two types of fronds (fertile and sterile) that often differ videly in appearance. The arrangement, location, and number of sori are ften used to identify species of ferns.

When the sporangia reach maturity, they dry and eventually split open vith enough force to release reproductive spores. These spores may be arried long distances by wind currents. If the place where it lands is uitable, the spore germinates and a new cycle of fern development begins, ventually resulting in a new fern plant. Fern sporangia may produce from 2 to over 500 spores each.

When fern fronds begin to grow in early spring, some of them have a olled-up appearance. The structure as it then appears is known as a iddle-head because of a resemblance to the head of a violin or fiddle.

These structures are considered delicacies; they are cooked and erved as a vegetable, and sometimes are canned commercially.

Fern fronds are borne on stalks or petioles called *stipes*. The central haft of the frond is called the *rachis*. The fronds bear leaflets, called *pinnae* singular *pinna*), at right angles to the stipe or rachis. When the pinna is the mallest division, a frond is described as pinnately compound. In some erns there is a further breakdown of the pinnae into units called *pinnules*. hen the structure is described as a double compound frond.

The three most common fern families in the Blue Ridge are the Polyodiaceae known as true or common ferns, the Osmundaceae or royal erns, and the Ophioglossaceae or adders-tongue ferns.

The flowering fern members have wings at the bases of the stipes, ar produce clusters of fronds from a husky rhizome. The fertile fronds a usually smaller than the sterile fronds, and produce clusters of sporang that seemingly resemble clusters of tiny flowers. Hence, the comm family name which is descriptive if inaccurate. Flowering ferns are usual large plants.

Fronds on members of the true fern family vary greatly in shape ar size, but most are smaller than on flowering ferns. They always bear the sori on the underside of fertile fronds. In the spring they form typic fiddle-heads as they emerge from the ground.

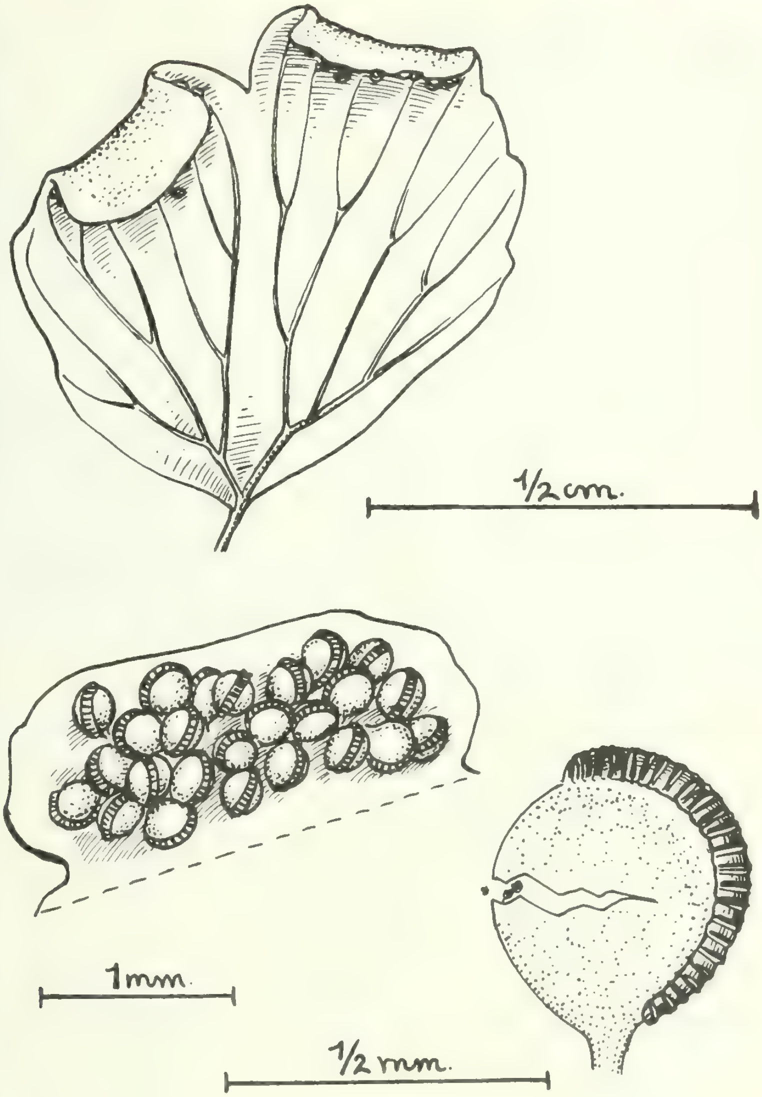
The adders-tongue ferns are small and have one to three muc compounded fronds. The sporangia are produced on a long-stalked part the fertile frond. Sterile fronds are triangular.

In the past, some ferns were used to treat diseases. *Asplenium*, t spleenwort, was used for worms in humans. Many Polypodiaceae or tr ferns contain a thick mucilage which was used for a range of diseases. T rhizome has been eaten, and in Hawaii the fronds of one species are used perfume coconut oil.

Indians used decoctions of spleenwort roots as an eyewash, for che pains, and to induce milk flow in nursing mothers. The maidenhair fern ro was used against diarrhea and for pediatric problems. *Polypodium* plan were used to treat dizziness and headache and something similar to dip theria in children. A decoction of the aboveground parts was used f venereal disease. Various species of *Dryopteris* were believed to comb shellfish poisoning and stomach aches.

Caution: Mention of former medicinal uses does not imply that the trea ments are effective. Under no circumstances should these plan be used for self-medication.

REPRODUCTION OF FERNS



Upper: Sori borne on the end of a vein on a frond, and covered by the turned-over edge of the leaf.

Middle: Sori on a frond.

Lower: A mature sorus splitting open and ejecting spores.

POLYPODIACEAE Fern Family

Maidenhair fern. *Adiantum pedatum* L.

The fronds are forked and spreading, growing 6 to 24 inches in height. The stipe of the petiole has a purple tinge and is markedly shiny. This species grows in rich, calcareous, shaded, humid areas.

Ebony spleenwort. *Asplenium platyneuron* (L.) Oakes

This evergreen fern has fertile fronds, which grow to 15 inches in height, and are slightly tufted. Stipes are purple or brown, and shiny. Sterile fronds are shorter; sori are very numerous. This fern prefers shaded, moist woody areas.

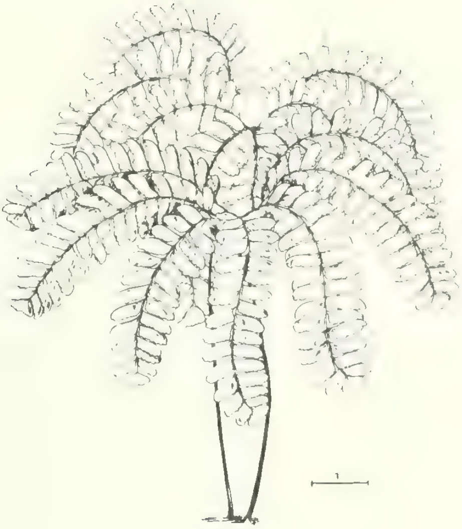
Southern lady fern. *Athyrium asplenioides* (Michx.) A. A. Eaton

The yellow-green fronds are 12 to 36 inches tall, with the sterile fronds shorter and broader than the fertile fronds. After June or July, the plants may have a brown-rust color. This species may occur under conditions ranging from dense woods to half-shaded fields.

Hay-scented fern. *Dennstaedtia punctilobula* (Michx.) Moore

The fronds when crushed produce a sweet, haylike odor. The fronds, delicate and slightly downy on the underside, range in size from 12 to 36 inches. Unlike the other ferns in the area, this one prefers open sunny areas.

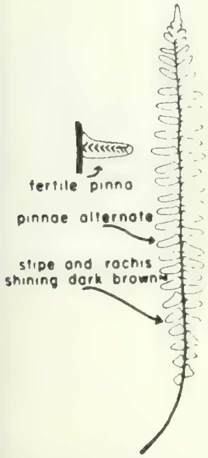
FERN FAMILY



Maidenhair fern

Southern Lady fern

Hay-Scented fern



Spleenwort

Mountain wood fern. *Dryopteris campyloptera* Clarkson

This fern is doubly pinnate, with triangular pinnae below. The fronds may grow to 2 feet in length and vary from evergreen to partially evergreen. It is found in Julian Price Park in North Carolina.

Broad beech fern. *D. hexagonoptera* (Michx.) Christens.

The fronds are 12 to 15 inches long, triangular in shape, and usually broader than long. The lower frond surface is downy. Basal segments of pinnae form a wing along the rachis. It prefers shaded, moist woods but grows in a range of situations.

Marginal shield fern. *D. marginalis* (L.) Gray

An evergreen, or almost evergreen, with dark-green leathery fronds, 5 to 8 inches across, up to 18 inches in height. The sori are borne along the margins. Fronds occur in dense clusters. This species is found on rocky wooded slopes, usually in full shade.

New York fern. *D. noveoboraciensis* (L.) Gray

The fruiting bodies are found near the frond margins. The fronds vary from 12 to 24 inches in length, and taper markedly at the basal and terminal ends. The lowest pinnae often are shorter than the middle ones. This species is found most often in moist forest areas.

Spinulose (spiny) shield fern. *D. spinulosa* (O. F. Muell.) Watt

The fronds often seem to be growing in a row, are about 18 inches long or 6 inches wide, and are almost evergreen. They often are found growing near rotting stumps of trees. The species prefers damp places such as swamps and bogs.

FERN FAMILY

ginal Shield
fern

New York fern

Spiny Shield
fern

ad Beech fern

Wood fern

Sensitive fern. *Onoclea sensibilis* L.

This fern is usually partially evergreen. The erect fertile fronds, 2½ feet tall, usually growing in the middle of the plant, survive all winter, and the sterile, triangular fronds die in the fall. The fertile fronds have a beadlike appearance as the pinnules roll up, covering the sori. The pinnules of sterile fronds are opposite, and the rachis is winged. A folk tale tells that when the fern is picked, the fronds close. This species prefers high moisture and at least partial shade.

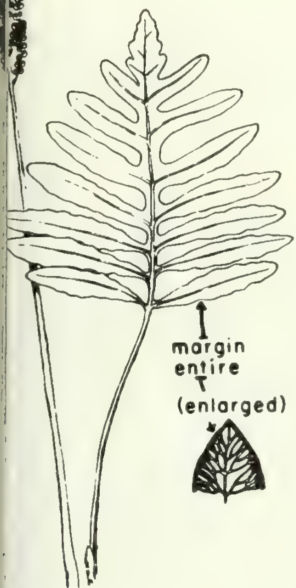
Resurrection fern. *Polypodium polypodioides* (L.) Watt

Fronds are yellowish green with a leathery texture. They are about 6 inches tall and 1 to 2 inches wide. The lower surface may appear to be gray. During prolonged dry periods, the fronds may roll up or even die back, but they quickly revive when rain falls. This fern is common on rocks, on the upper sides of limbs, and on trunks of trees.

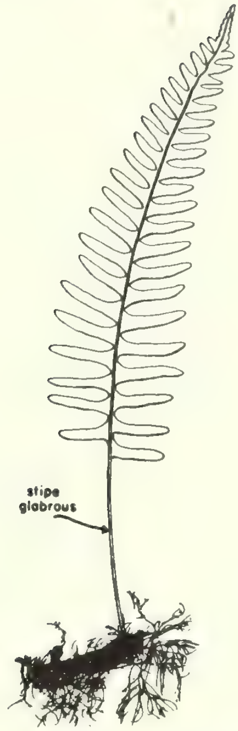
Common polypody. *P. virginianum* L.

Fronds are evergreen, erect, up to 12 inches in height and 2 inches wide. Shading is quite variable. The sori are produced between the frond border and the midrib. This stipe is glabrous. This fern grows on rocks and logs.

FERN FAMILY



Sensitive fern



Common polypody

Resurrection fern

Christmas fern. *Polystichum acrostichoides* (Michx.) Schott

This fern is found in a range of forms. The brown fruiting bodies on the underside of the fronds are arranged in several patterns, but fertile pinnae are always at the tip of the frond. The fronds vary in size from 6 to 20 inches. The upper or spore-bearing pinnae are smoother than the lower or sterile fronds. The species prefers shaded, moist areas.

Bracken. *Pteridium aquilinium* (L.) Kuhn

One of the largest ferns, this species may have fronds ranging up to 6 feet tall. It is not easily confused with others in the Blue Ridge. The fronds are somewhat lance shaped. Sori occur in a continuous band around the outer margin of the pinnae. This fern grows in fields and thick woods.

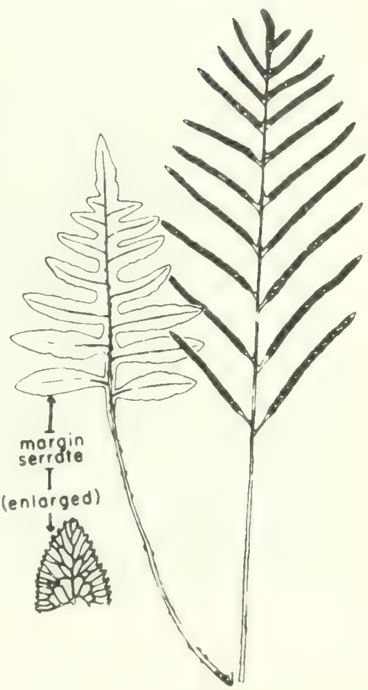
Chain fern. *Woodwardia aerolata* (L.) Moore

The sterile fronds vary from 8 inches to 2 feet in height, and have green petioles, and look much like sensitive ferns. Pinnae in this species, however, are alternate and have serrated margins. The fertile fronds are taller and have dark-colored petioles. The sori are produced on each side of the midvein of the fertile fronds, and resemble two rows of chain links. Midveins of sterile fronds also have two rows of chain links. The species prefers filtered, partial light and damp areas.

FERN FAMILY

Bracken fern

Christmas fern



Chain fern

OSMUNDACEAE Osmunda Family

Three species in this family are found in the Blue Ridge. All three prefer damp woods. All have stipes winged at the base. All are large and coarse with erect or somewhat spreading fronds. The species differ primarily in the appearance of sori and spores.

Cinnamon fern. *O. cinnamonea* L.

The name of this fern comes from the brown cinnamon appearance of the young fronds and stalks. The sterile fronds range from 2 to 5 feet in height and are much taller than the fertile fronds, which are fuzzy at first, and soon dry. The sori are a bright cinnamon brown. Plants are often blue green. This species prefers wet areas.

Royal fern. *O. regalis* L.

The sori are borne at the top of a fertile frond. The long-stalked fronds range from 1 to 5 feet long, but sometimes are over 5 feet. The arrangements of pinnae resemble locust leaves, and another common name is locust fern. The fertile fronds have few pinnae, widely separated and tipped by the sporangia. The sterile fronds have more pinnae. The spores are light brown to tan. In early spring the fronds are pink hued. This fern prefers wet areas such as swamps, marshes, and damp woods.

Interrupted fern. *O. claytoniana* L.

This fern differs from the other two in that it bears sporangia in the middle or near the base of a fertile frond. Fertile fronds have several pairs of small blackish pinnae, which give the plant a unique appearance. The upright fronds,which taper at the base and at the apex, grow to 5 feet in height. This fern prefers dry, open glades.

OSMUNDA FAMILY

Interrupted fern

yal fern

Cinnamon fern

OPHIOGLOSSACEAE Adders-tongue Ferns

Rattlesnake fern. *Botrychium virginianum* (L.) Sw.

This fern seldom exceeds 2 feet in height. It usually produces a sin evergreen frond, although it may have two or three. The fertile portio produced on a long stem on which the tightly clustered pinnae sligh resemble a snake rattle. The fern was once believed to be a sure indicato the presence of ginseng. It grows in heavy woods, in well-drained soils.

SOURCES OF ILLUSTRATIONS

We thank Seneca Books, Inc., publisher of "Flora of West Virgini and the authors of that book, P. D. Strausbaugh and Earl L. Core, for us their illustrations of ebony spleenwort, southern lady fern, rattlesn fern, hay-scented fern, mountain wood fern, marginal shield fern, sp shield fern, sensitive fern, interrupted fern, broad beech fern, resurrect fern, common polypody, and chain fern.

We also thank the New York Botanical Garden Library for its illus tion of *Dryopteris noveboracensis*.

ADDERS-TONGUE FAMILY

Rattlesnake fern

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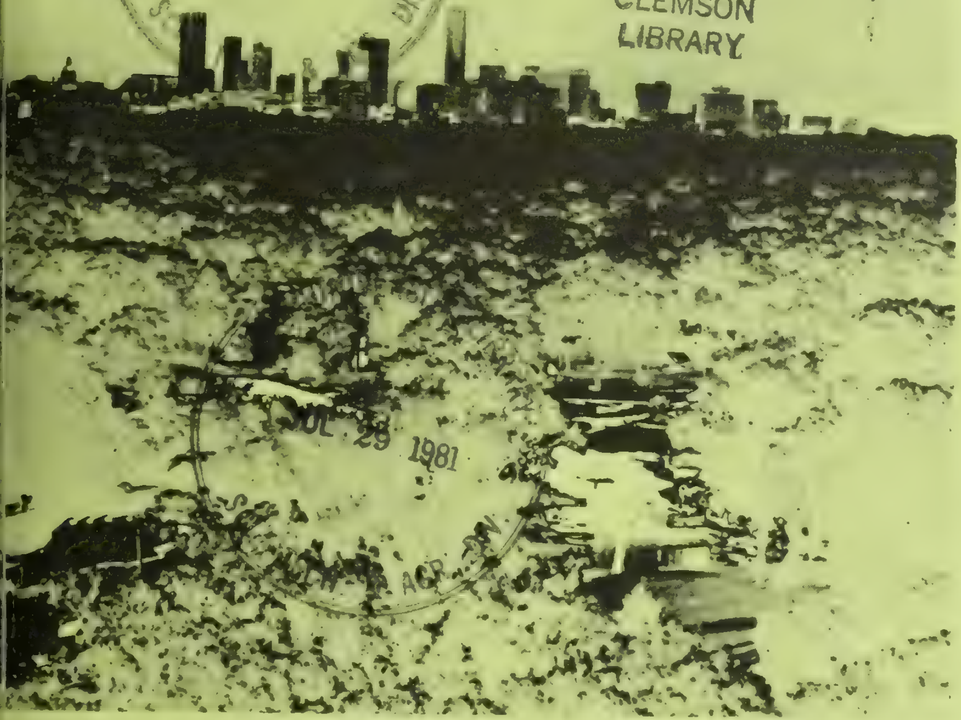
ban Waste Wood Utilization

Proceedings of a Conference on Alternatives to Urban Waste Wood Disposal



March 26-28, 1979

Charleston, South Carolina

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Southeastern Forest Experiment Station
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URBAN WASTE WOOD UTILIZATION

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TOPIC I
THE RESOURCE SITUATION

ABSTRACTS

CORDELL and CLEMENTS

Urban Waste Wood: A National Perspective.–Large amounts of metropolitan solid (MSW) are produced each year in this country. Of this potentially important resource waste is vastly underutilized. In the future, recovery and reuse of wood waste will be more viable and attractive option. Comprehensive study of the resource and alternati grams of utilization are needed.

DENNISON

FIBREST–A Tool for Quantifying and Qualifying Wood Residues. A compu accounting system, FIBREST, has been developed to aid the assessment of wood fit dues generated in urban areas. Computed from survey questionnaires, residue amou be reported by industry, county, and town/city sources in 10 form categories and 3 d classes.

LOGGINS

Composition of Landfilled Urban Waste Residues. Purpose of the study was to det various quantities of wood waste being landfilled in the Atlanta metropolitan area. A was completed during the summers of 1977 and 1978. Information collected empha large volume of potentially useful urban wood residue that was being wasted.

DAVIS

Source Separation–Procedures and Practices.–Urban programs in source separation o wood in New Jersey center economically on two types of programs, those which remuneration and those which do not. Those with a future tied only to the public- aspect appear to have the greatest potential for survival.

COMMINS

Determination of Wood Content in Demolition and Construction Wastes.–Demoliti construction waste streams were evaluated on a national basis by a unique combina empirical and predictive techniques. National figures developed indicate 55 million to waste wood fraction of which is 22 million tons, representing 2 percent of the heatin of all U.S. coal production.

URBAN WASTE WOOD: A NATIONAL PERSPECTIVE

H. Ken Cordell and Thomas W. Clements[1]

Abstract.—Large amounts of metropolitan solid wastes (MSW) are produced each year in this country. Of this potentially important resource, wood waste is vastly underutilized. In the future, recovery and reuse of wood waste will become a more viable and attractive option. Comprehensive study of the resource and alternative programs of utilization are needed.

A tour of any landfill in any metropolitan U.S. city in any year will reveal that mericans, either as individuals or through business or government, are discarding rge amounts of possibly reusable material. Over 90 percent of this metropolitan lid waste (MSW) is landfilled, burned, or dumped into the ocean each year (Grinead 1970).

Methods of raw material extraction and refinement and product manufacture d distribution have been in the center of technological and economic concern. But ese systems, coupled with social concerns, have noticeably excluded the recovery of lid waste. Modern methods of managing solid waste as a resource are only slowly ing incorporated. In light of a growing population, increasing prosperity and conmption, and a diminishing resource base, it is of vital importance that waste of all rts be reduced through methods of solid waste recovery.

The U.S. Forest Service is charged under the National Forest Management Act of 76 (U.S. Congress 1976a) to investigate the recovery of waste wood materials. rough this investigation, it is hoped, a more conscientious program of resource utiliation will evolve. Urban waste wood is an integral part of such management.

ESTIMATES OF QUANTITY

There are many different and somewhat conflicting estimates of the amount of lid wastes in the Nation. Among these, figures from the Environmental Protection gency give an idea of the magnitude of the solid waste resource in the United States. r 1971, EPA estimated that nationally there were 4.45 billion tons of solid waste. ese estimates include much mill and mining waste, most of which is rurally located. od and paper, however, make up significant proportions of the solid waste total: weight, in 1975, about 4 percent was wood. The dramatic increase in product packing since 1945 is largely responsible for these high percentages.

Wood reuse, particularly of manufacturing waste, is increasing. In 1974, the SDA report entitled "The Outlook for Timber in the United States" indicated that proximately 2.8 billion cubic feet of slabs, sawdust, veneer cores, and other such aterials were being reused for particleboard, pulp, fuel, and other products (USDA

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[1]The authors are, respectively: H. Ken Cordell, Project Leader, Urban Forestry Research in the uth, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, Georgia; d Thomas W. Clements, Research Technician, Urban Forestry Research in the South, Southeaste Forest Experiment Station, Forestry Sciences Laboratory, Athens, Georgia.

FS 1974). This figure represents an 18-fold increase since 1952; however, in 1
1 billion cubic feet of manufacturing waste wood still was not being used.

It is important to note that urban waste wood in general is much more con
nated than manufacturing wood residues. EPA estimates that of the nearly 5 b
tons of solid waste, about 9 percent (450 million tons) is classified as MSW. Of
MSW, about 3.6 percent (16.4 million tons) is wood. This wood is mixed with
joined to all manner of debris. Reuse of urban waste wood is a complex underta

Estimates of the amounts of urban waste wood, by source and use, have
provided by Carr (1978). Table 1 shows that urban waste wood totals about 16.4
lion tons and urban waste paper about 44.5 million tons. Together these total 61
lion tons of reusable resources.

Table 1.—Sources and uses of urban wood waste (approximate annual figures)

Source	Quantity (air-dry tons)	
	Million	*Percent*
Wastepaper	44.515	73
Waste timber products	13.662	22
Trees	2.800	5
Total	60.977	100

Current disposals of these wastes are for:

	Quantity
Fiber and Allied Products	*Million*
Wastepaper	12.330
Waste timber products	1.697
Trees	0.140
Total	14.167
Energy	
Wastepaper	1.000
Waste timber products	1.814
Trees	0.280
Total	3.094
Landfill, Dump, Incineration, etc.	
Wastepaper	31.185
Waste timber products	10.151
Trees	2.380
Total	43.716

Total resource recovery (fiber and allied products of energy) equals 17.261 million tons, or 28
percent of annual formation.

Of this total, only 28 percent (17 million tons) currently is being used (fig. 1). ses include fiber and allied products (14 million tons, 82 percent) and energy (3 mil-
on tons, 18 percent), as shown in figure 2. Seventy-two percent (44 million tons) rrently goes into landfills or is incinerated.

Large cities have massive amounts of waste wood. For example, Chicago has timated its wood to exceed 400,000 tons; Atlanta has about 75,000 tons per year d 80,000 cubic yards of leaves; and Minneapolis-St. Paul has over 300,000 tons of n waste wood alone per year.

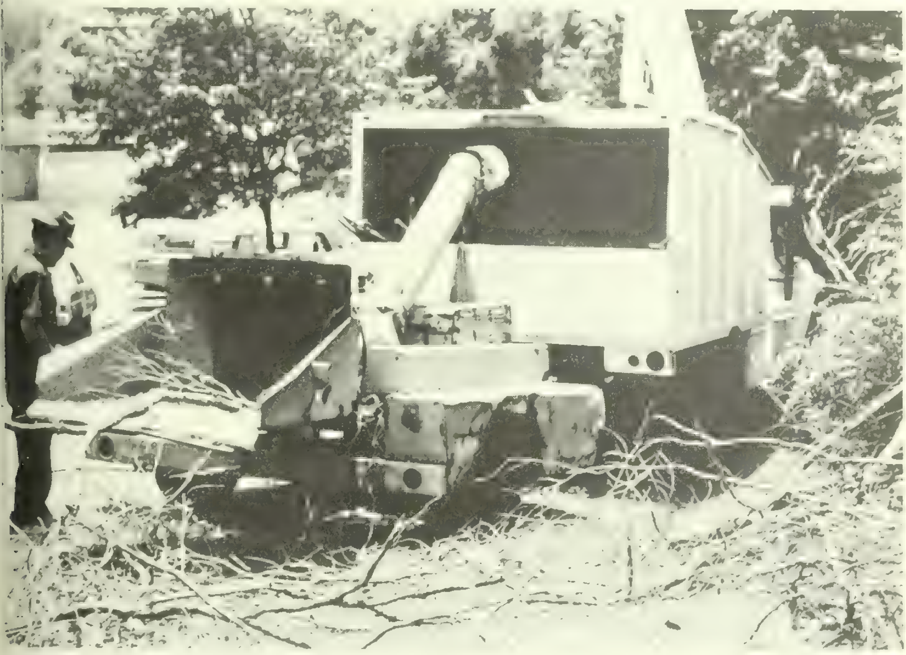

Figure 1.–Chipping of Dutch elm diseased trees on the University of Georgia campus.

SOURCES OF URBAN WOOD

The major sources of urban waste wood are: municipal agencies, which remove ood from residential trimmings, construction sites, and street trees; commercial ers, who discard such things as pallets and packaging; and industries that manufac- re finished products such as furniture.

Waste timber products account for 13.662 million air-dry tons per year and tree sposal 2 million air-dry tons per year. Of the waste timber products, 47 percent is molition debris, 31 percent is pallets and containers, 4 percent is dunnage, and percent is from wood product manufacturing (Carr 1978).

According to "The Outlook for Timber in the United States" (USDA FS 1974), out 900,000 units of housing are demolished each year. Because about 75 percent of

Figure 2.—Wood chips falling from a tire shredder—Cobb County, Georgia, landfill—may be util by paper companies.

the U.S. population lives in urban areas, most of this housing demolition is urban.

Demolition wastes are, unfortunately, not homogeneous and thus pose probl in the removal of contaminating nonwood materials. But the sheer volume of resource coming from easily identified points of origin strongly favors reusing tl wastes.

Housing starts also contribute huge volumes. Estimates are that about 2.5 mil new units of housing will be built each year during the 1970's (USDA FS 19 Unused construction lumber and trimmings increase as the number of new u increases. A report for the EPA by the JACA Corporation (1977) estimates tonr for construction and demolition waste at 21.9 million tons annually. Demolition w wood accounts for 19.3 million tons, and construction wastes account for 2.6 mil tons.

Certain forms of packaging, especially at the retail level, are used only once before disposal. Heavy-duty packaging such as crates, boxes, and dunnage may be reused industrially and commercially, even though lifespans are short. Pallets have a lifespan of about 3 years (USDA FS 1974) before they enter the waste stream. Approximately 205 million pallets were made in 1974 (USDA FS 1974), so there should be an even larger number entering the waste stream today. Better design and use of stronger materials may lengthen their lifespan, but in time all these materials will become waste.

The greatest single contributor of waste wood in many cities is municipal government itself. Since the government must prune and remove a large number of trees on municipal lands and streets and since the average lifespan for a city tree is only 10 years, it is not surprising that large volumes of tree removal and pruning materials are generated.

Dutch elm disease alone has had great impact on the vegetative cover of many cities (fig. 1), especially northern cities where more than half of the planted trees were elm. In cities such as Chicago and Minneapolis-St. Paul, there is a flood of elm wood. Leaves and limbs of elm trees have a high volume-to-weight ratio and create problems at landfills where fill space is very limited. Utilization of this elm wood would be very beneficial.

LEGISLATION CONCERNING WASTE WOOD

Laws in the United States to encourage recycling or to discourage waste are few and weak. The problems and some opportunities with solid wastes have been recognized for many years, but the approach has been to dispose of solid waste rather than to reuse it.

The Solid Waste Disposal Act of 1965 (U.S. Congress 1965) was one of the first attempts by Congress to address the issue. Its main focus was on dump and landfill practices and on environmental protection through safer disposal procedures. The Act also called for conservation of natural resources by reducing solid waste disposal.

The Resource Conservation and Recovery Act of 1976 (U.S. Congress 1976b) is full of language encouraging—and even requiring—planning to recover materials from solid waste. Each state is required, under the guidelines of the Act, to have in its solid waste management plan some discussion of recovery and recycling; however, there are no requirements for implementation of those plans, so participation is voluntary.

The U.S. Forest Service is involved in the recovery of urban waste wood through the National Forest Management Act of 1976 (U.S. Congress 1976a). The Forest Service has a legislative mandate to determine the reuse potential of urban waste wood, but the reduction of waste, which is a key to the problem, is not addressed.

An innovative program was begun by the State of Oregon in 1967 to encourage recycling and environmental protection. A law was passed which provides tax relief "to encourage the construction, installation, and use of facilities to prevent, control, or reduce air, noise, or water pollution and to utilize solid waste by providing tax relief for persons who do so" (State of Oregon 1967, Sec. 1). The law was amended in 1973 and 1975 to allow for tax benefits to certified solid waste facilities. "Such a facility to be certified must produce as an end product a usable source of power or other item of real economic value . . ." (State of Oregon 1967, Sec. 2.B).

REUSE PROGRAMS IN THE UNITED STATES

In the U.S. it is difficult to find successful urban waste wood recovery progr which are not tied to energy production. Either there is not enough information ab nonenergy uses, or the economic returns from such uses have not been sufficient. M likely, this lack of success has been due to the new interest in recycling resour which has only recently prompted investigation of utilization methods.

Use of wood for energy is perhaps the easiest option, since energy is a unive use for all forms of wood. But this is a final use; the possibility for any further reus gone once the wood is converted to energy.

Other uses of wood include transformation into other products, such as parti board or woodchip mulch. From many of these uses, production of energy from wa wood is still an option.

USE FOR ENERGY

Numerous wood-processing companies have begun to use their own waste wood supplement the energy needed for their operations. It has become standard proced for companies such as Weyerhaeuser and Georgia-Pacific to burn waste wood energy rather than to dispose of it. Most of these plants are located in rural areas little urban waste wood is involved, though use of urban waste wood by paper com nies in Georgia has been investigated. Wood from the Cobb County landfill (in Me Atlanta) has interested Georgia Kraft, and wood from the Chatham County (Savann landfill is wanted by Union Camp. At both landfill sites, the incoming wood would chipped and transported to the plant site (fig. 2).

In another example, wood from the DeKalb County landfill (near Atlanta already being chipped and sold. The results are not very promising at this time, h ever, because of small volumes of wood.

In Portland, Oregon, a company called Grenco, Inc., is purchasing dunna pallets, demolition debris, and other waste wood from manufacturers. By a chipp and contaminant separation process, they are creating material used as boiler fuel in hardboard manufacturing. Reports from the plant indicate a steady delivery chipped demolition debris from Portland to energy users.

Large-scale use of wood for fuel to produce electricity is underway in Burlingt Vermont. The city is now operating a 10-megawatt generation plant fired solely wood. Burlington also is building a new 50-megawatt plant. Some urban garbage c taining urban waste wood will be burned in this new plant. Two tons/hour/megawat needed for electricity generation; thus, a larger amount of wood is needed than co possibly be provided through use of the city's waste wood.

Pelletizing wood to be burned for energy is apparently gaining acceptance. A lea in the use of this process is Woodex, Inc., of Brownsville, Oregon. The plant is parti larly efficient and has a daily capacity of 125 to 300 tons of wood and agricultu waste. Although this plant uses mostly logging wastes, the process demonstrate technology applicable to urban waste wood.

Different methods to derive energy from wood are through pyrolysis and gas cation. In both processes, wood is subjected to high temperatures in an oxygen-p

environment, converting the wood into either oil, gas, or combustible char.

The Georgia Forestry Commission has been involved in research on these methods, and two companies in Atlanta are currently using gasification to operate hardwood dry kilns. Although urban wood is not currently used very much, application of this technology seems to be viable. The State of California is investigating pyrolysis of agricultural wastes. A number of cities are either burning their garbage for energy or planning to do so. Since wood is only a small constituent of this garbage, these efforts are of only passing interest. Ames, Iowa, is perhaps the best-known example of solid waste disposal through burning of refuse for fuel. The U.S. Navy has also been a leader in this area.

Tacoma, Washington, and Columbus, Ohio, are soon to begin energy recovery from garbage. This is "high technology" since large amounts of machinery and energy are necessary to keep the process going. A low technology approach to the garbage problems would be source separation where different kinds of recoverables, such as glass, paper, metal, and wood are separated at the point of discard, such as a home or business.

A few cities have been involved in impressive attempts to solve their waste wood problems. In these attempts, energy production has been the major product in cities such as Chicago, Madison, and Minneapolis-St. Paul. The amount of wood in Chicago could be as high as 1,000 tons of ovendry material per day. Estimates are that Chicago and surrounding municipalities remove 450,000 tons of tree debris annually and that dunnage and demolition waste may exceed 200,000 tons annually. The city hoped to find someone to utilize this waste wood for conversion to energy when it began looking at the problem in 1976.

Commonwealth Edison, the major energy producer in Illinois, had no interest in this waste wood, however, because of perceived technical and economic drawbacks. Other potential sources were identified, including Grenco Company of Portland, Oregon, but no guaranteed outlet for disposal was located.

The Metropolitan Sanitary District of Chicago also expressed an interest in the use of chips with their sludge composing project. Hopes for large-scale uses of Chicago's wood debris through burning, particleboard manufacture, or other use, however, have not been realized. Costs of collection, separation of foreign matter, processing, storage, and transportation have thus far seemed too high.

Madison, Wisconsin, and St. Paul are other cities which have actively studied the possibilities of using waste wood. Only limited success has thus far been realized.

NONENERGY FORMS OF REUSE

The number of programs, successful or otherwise, involving recovery of nonenergy waste wood is relatively small. But there are signs that technology is being generated and that some success is being achieved. Perhaps the simplest type of operation is represented by a project established in Birmingham by the Alabama Forestry Commission. At a recycling center, paper, glass, and aluminum are brought in, already separated, and exchanged for firewood or wood chips from trees on city lands. In this manner, the recycling center is paying for itself through receipts from materials sold.

Birmingham, which earlier was uninterested in the project, has recently expressed strong interest in becoming more active in such an operation. Huntsville, Alabama, is undertaking a similar project. These low technology operations may be a key to future waste disposal. The cost of separation is spread over large numbers of people, as perhaps it should be.

Other cities involved in nonconventional waste wood disposal include Toledo, Ohio; Lansing, Michigan; and Atlanta. Lansing, forced by law to eliminate landfilling and open burning of wood, adopted incineration and utilization through production of firewood, rough lumber, wood chips, bark chips, and sawdust. In 1970, that utilization program, run by a private company, went bankrupt and the city began chipping all of its own small wood to use on trails, as mulch in flower beds, and for various uses in parks. All other waste wood that the city generates is taken to a firewood yard which is open, 2 days a week, to residents.

Toledo, Ohio, also forced to eliminate open burning, devised a recycling program for brush and logs. End products anticipated from the operation were: wood chips for mulch in city parks, logwood chips for paper companies, firewood for public sale, fencing and pavers, and solid logs for use in playgrounds or for sale to sawmills. Down time caused by damage to machinery from metal contaminants in the wood caused problems in the operating costs, but officials felt that what is being learned about the use of waste wood and the environmental benefits assure that the effort will eventually pay off.

Atlanta has successfully implemented a program to divert city-generated waste wood from being landfilled. The city has over 5,000 miles of rights-of-way and 4,000 acres of municipal land to maintain. On these lands there are an estimated 1.5 million trees under the city's care. Normal maintenance produces large amounts of waste wood from pruning and removal. The Atlanta program involves: free firewood yards, wood chips, and composting. The programs to use self-generated waste run smoothly in Atlanta, but thousands of tons of private waste wood are still not reused and continue to be landfilled.

Use of wood chips with sludge composting has been subject to experimentation at the U.S. Department of Agriculture test facility in Beltsville, Maryland. Implementation of a sludge composting project has occurred also in Ft. Lauderdale, Florida. Wood from construction sites is purchased, chipped, and then mixed with sludge to allow aeration, which causes quicker breakdown of the sludge.

Kellbro Corporation in Sacramento, California, makes mulch and garden additives from mill wastes, demolition wastes, and street trees. The company was producing a fiberboard from waste until its sources were depleted, but success with its mulching product seems to be established.

The manufacture of fiberboard and chipboard is a growing industry because of better technology. The Medford Corporation in Medford, Oregon, makes a medium density fiberboard utilizing plywood trim, planer shavings, and sawdust. The material is refined and reduced to wood fiber, dried, and formed with resin into boards. Most of this waste material is not now urban, but much of it would be landfilled or burned if not used for fiberboard.

Williard's Sawmill in Trenton, New Jersey, is another example of urban waste wood reuse. Trees cut from city rights-of-way and from private lands are purchased by the sawmill and made into special products, including tabletops, plaques, clockfaces, and lumber.

One successful program is administered by the New Jersey Bureau of Forestry. Through this program, businesses generating wood residue are matched with those which have a use for the materials. This Statewide program began with a preliminary feasibility study in 1970 and was implemented in 1972. Currently, four people are working with the project.

Examples of reuse include sale of turned material to a toy manufacturer and sale of bay-window corners to a company which makes plaques and foot pedals for drums. In 1977 about 2 million cubic feet of waste wood were recycled, with a savings of over $900,000 to New Jersey businesses.

A thorough inventory of industry in a city or region would discover possibilities for more efficient reuse of waste wood.

SUMMARY AND CONCLUSIONS

Our estimates of the amount of MSW are not very good at this time. Generally, we estimate that there are approximately 500 million air-dry tons of MSW annually. Between 16 and 17 million tons of this MSW are some form of wood. Of this, we currently use only 28 percent for products or energy.

As is the case with solid waste in general in the U.S., we seem to be vastly under-utilizing a potentially important resource. It is our strong conviction that, for a number of reasons, recovery and reuse of urban wood waste will become a more viable and attractive option in the near future. To realize the full potential of this option, we should now begin planning programs and conducting research (fig. 3). Our reasons for suggesting the growing feasibility of urban waste wood recovery include:

Figure 3.—Whole-tree chippers, as used here by Georgia Forestry Commission, may be useful in future urban wood utilization programs.

1. Rising costs and decreasing availability of forest-derived, primary wood f
paper, fiberboard, and similar manufacturing are making alternative sources of wo
fiber more attractive. Income derived from using urban waste wood, even though n
enough to cover recovery costs, will help offset the costs of waste disposal. This pote
tial income should continue to increase at least as fast as disposal costs and thus shou
be viewed as a buffer against rising costs.

2. Demand and costs for energy are rising at high rates. As the cost of ener
increases relative to other costs, the option of using wood (and other organic waste
for energy production becomes more attractive. The Energy Research and Develo
ment Administration has estimated that by 1985 the U.S. will have a quantity of so
waste available to produce the equivalent of 500,000 barrels of oil per day.

3. Costs for landfilling operations and sites are increasing. In addition, space f
landfilling is becoming limited, to the extent that locations are often difficult to fin
As these costs rise, resource recovery and waste wood utilization become more a
more attractive as a means of reducing disposal costs for all solid wastes. Comprehe
sive recovery programs can reduce solid waste volumes by 75 to 95 percent.

4. Technology for waste wood recovery seems to be in its infancy. Syste
designed to produce energy, separate usable wood and other resources, and involve t
public have been tested in only a few locations for relatively short periods of tim
thus, some of the negative conclusions are perhaps premature. There are too ma
success stories and too many changing conditions to conclude that wood recovery
not feasible. We should keep in mind that there are many objectives involved. Amo
these are: environmental protection through reduction of solid waste; resource cons
vation through reuse; and partial cost recovery.

If we look only at any one of these, waste wood recovery can be viewed as a failu
If we consider all simultaneously, acceptable and sufficient returns will be realized.

One of the bigger needs in this area is for comprehensive study of the resourc
alternative programs of utilization, and the cost-return schedules associated with ea
alternative. Thus far we really haven't done this.

Ultimately we will have to reuse whatever resources we can. We should beg
planning and testing alternatives now so that we are prepared for these future nee
and so that we are creating a better urban environment.

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FIBREST A TOOL FOR QUANTIFYING AND QUALIFYING WOOD RESIDUES

Steven E. Dennison[1]

Abstract.—A computerized accounting system, FIBREST, has been developed to aid the assessment of wood fiber residues generated in urban areas. Computed from survey questionnaires, residue amounts can be reported by industry, county, and town/city sources in 10 form categories and 3 disposal classes.

INTRODUCTION

Wood fiber waste is produced in a wide array for forms, types, and conditio Familiar examples are sawdust, bark, edgings, trim, and various types of paper mat als. Other types include pallets, telephone poles, broken furniture, wooden containe and limbs and brush from yard and tree maintenance.

Depending upon the source, one or more types of residue may be generated at t same locale. Sawmills generate bark, sawdust, edgings, trim, and chips as byproduc Residential and commercial sources produce newsprint, cardboard, crates, and pall as discards, while a printing and publishing firm may throw away paper cutoffs a trim.

Our failure to apply either modern management or modern technology to t ultimate disposal of this abundance has resulted in a monumental solid waste proble Federal legislation, such as the Solid Waste Disposal Act of 1965 (Black 1970), t Resource Conservation and Recovery Act of 1976 (McGlennon 1977), and the N tional Forest Management Act of 1976 (Foley 1976), has focused attention on t need for recovery of these materials from the Nation's trash.

Approaching the problem from another aspect, many states and communit (Mass. DEH 1971; Massey and Dunlap 1975; US EPA 1975) are setting specific gui lines for sanitary landfills to cope with the volume of waste material. These guideli may include strict regulations for burning, salvage operations, and the disposal woody materials. In the last decade, municipal governments, wood-using industri and other private firms have also been turning to these solid waste piles as a source material to help defray the rising costs of energy, raw material, and disposal.

WASTE MEASUREMENT

For the potential user of residue materials, information must be obtained on th availability and reliability as a resource, their location, and the forms in which they generated; however, to date there have been no consistent, comprehensive methods f collecting and reporting this information. The heterogeneous nature of residue ma rial makes detailed measurement difficult. As a result, most of the completed inve tories were done for specific reasons and the results reported in an array of units, th making comparisons difficult.

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Several efforts aimed at waste analysis (Combustion Engineering 1969; Ingram and Francia 1968; Muhich and others 1968) were undertaken using funds provided by the Solid Waste Management Act of 1965. These studies, for the most part, were national in scope and resulted in the reporting of waste-per-capita averages for the country as a whole.

A new approach in the prediction of solid waste amounts and components was introduced by the URS Research Company (Black and others 1972) in 1971, under contract with the U.S. Environmental Protection Agency. This method uses a material flow locus which assumes that waste generated in an area is derived primarily from the goods and services consumed in that area. A synthesis approach is used in which estimates and predictions of residuals are based on knowledge of materials and quantities before they become a part of the solid waste stream.

Despite the obvious advantages of this system, it is not without its drawbacks - the main one being the cost of implementing the system. An inventory of all waste-producing activities in an area must be conducted to compile standard information on the materials consumed per unit size and time for each activity type, as well as to define which of these materials become waste. Smith (1975) also points out that wastes not passing through a production sector (e.g., removal of street trees) will cause incorrect estimates in using this type of system.

Other studies, such as those conducted by Burry (1975), Frame (1974), and Quink and others (1974), used surveys designed to quantify the multiple forms of wood residues in order to encourage their utilization. These canvasses, although inexpensive to implement and designed for specific purposes, found that conversion figures varied widely.

Because of the marginal value of wood wastes and the economic constraints surrounding materials flow data, residue inventories usually resort to the canvassing format. Letter questionnaires and personal interviews, if properly designed and pretested, provide a relatively easy and inexpensive method of data procurement. The major problem with this type of system is that there is no general form to follow in analyzing the data. Each inventory is unique when it comes to conversion figures and measurement units.

The remainder of this paper will discuss another inventory system, *FIB*er *R*esidue *EST*imation (FIBREST), which deals with the problems associated with the common canvassing format (Dennison 1977).

FIBREST SYSTEM

FIBREST is a wood residue computer-accounting system written in standard ANSI FORTRAN; it is designed to analyze industrial wood residues in urban areas. It examines survey returns, is flexible in its use, and attempts to present the output data in a rational, readable fashion.

It will accept a variety of measurement units, while providing an estimate of wood residue amounts in one reporting unit for a given region. FIBREST will report these amounts according to their location, their form, the degree to which they are contaminated, and how they are currently disposed.

SYSTEM INPUTS

Obtaining a list of wood residue generators (the starting point for conducting the inventory) is often the most arduous task of the whole process. Sources that would help in compiling this list may include state industrial directories, state and local Chamber of Commerce indexes, Extension Service lists, and as a last resort (although often a good source), the yellow pages and classified advertisements in the area to be surveyed.

As this information is obtained, each waste generator should be coded numerically by location (town, county, state, etc.) and by its Standard Industrial Classification (SIC) number. SIC codes can be found in the U.S. Department of Commerce's "Standard Industrial Classification Manual" (USOMB 1972). If waste producers other than industry are surveyed (e.g., city/town tree maintenance departments), other codes can be added. A partial listing of the types of wood residue generators which might be included is shown below.

SIC	Descriptor
0783	Ornamental shrub and tree services
1522	General contractors
1795	Wrecking and demolition crews
2421	Sawmills and planing mills
2448	Wood pallets and skids
2499	Miscellaneous wood products
2642	Envelopes
2711	Newspapers, publishing
3732	Boatbuilding and repairing
3994	Caskets

From this listing the FIBREST system is capable of handling a 100 percent sample or a partial sampling scheme.

SURVEY INFORMATION

Data requested on the questionnaire, in order to conform to FIBREST, should include:

1. The amount of residue produced (an estimate often has to suffice) in some unit and time period.
2. A percentage estimate of the amount produced in any or all of 10 different form classes (e.g., chips, pallets, paper).
3. A percentage estimate of the waste produced that is contaminated.
4. A percentage estimate of the waste material in each of the following categories: waste being used by the generator, waste that is sold or given away, and waste actually going to a disposal site.

Each survey response—the amount, the measurement unit, and the percentage in the above categories—is recorded in a consistent manner on computer processing cards according to SIC and locational codes.

AREA PARAMETERS

In order for the survey information to be properly sorted, other data must also be compiled and coded. These data include the SIC codes and descriptors being inventoried as well as the total number of firms in each class. Place names and locational codes of the governmental units and associated subunits of the area in the survey (e.g., counties and towns) are also used. Optional information includes populations as well as the number (and size) of disposal facilities in each subunit.

CONVERSION PARAMETERS

The uniqueness of FIBREST lies in its ability to accept the variety of measurement units associated with the residue amounts on the survey responses and to convert them to a specified reporting unit. It is this capacity that also allows for a comparison with other wood residue inventories.

The system constructs 12 tables, each containing a matrix of conversion figures. These figures are calculated from eight variables (supplied by the user) associated with wood fiber materials. For illustrative purposes, the variables used in a test of the program are listed below:

Moisture condition (green basis)	=	0.50 (dry is 50% of wet)
1 uncompacted cord	=	75.0 cubic feet
1 uncompacted cord	=	500.0 board feet
1 compacted cord	=	128.0 cubic feet
1 cord, softwood (uncompacted)	=	2.5 tons (green)
1 cord, hardwood (uncompacted)	=	3.0 tons (green)
1 cubic yard, paper (uncompacted)	=	190.0 pounds
1 cubic yard, paper (compacted)	=	500.0 pounds

The conversion tables are then used in FIBREST as each survey return is analyzed. Using the coded measurement unit on each response, the total amount of residue is converted to the predetermined reporting unit selected from the following list:

dry tons	wet tons
dry pounds	wet pounds
dry cubic feet	wet cubic feet
dry cubic yards	wet cubic yards
dry board feet	wet board feet
dry cords	wet cords

The system is currently being modified to include BTU as an additional reporting unit.

SYSTEM OUTPUTS

The residue amounts are calculated, expanded to totals, and sorted for each locatio unit (e.g., SIC, governmental units). The data are then generated by FIBREST in tab ular form. This accounting format allows the residue user to examine more accuratel the resource situation in the survey area.

In addition to choosing a reporting unit, the user of the system may choose any o all of the following forms of output:

1. Residue account, by the source of generation (SIC).
2. Residue account, by each major administrative unit (e.g., county).
3. Residue account, by each subunit (e.g., city/town).
4. Conversion tables.
5. Return statistics of the survey.
6. Multiple listings of the above choices.

If none of these options is chosen, the output consists of a single table summarizin the residue amounts in the surveyed area. This summary includes the physical compo nents (forms) of the residues and how they are disposed—all by each SIC (source) code Table 1 is a partial illustration of this summary table.

Table 1. Sample summary table showing physical components and disposal methods

Physical components	Type of wood residue generators				
	Shrub and tree services (0783)[1]	General wood products (2499)[1]	Envelopes (2642)[1]	Caskets (3994)[1]	Grand total
			Percent		
Wood fines		–	–	–	–
Sawdust		28	–	3	18
Edge trim		32	–	3	21
Limbs	48		–	–	16
Chips	43	2			15
Bark	6	1	–		3
Paper			100		0
Misc. board		24		–	16
Pallets		12		–	8
Other	3	1	–	94	3
Estimated total (Dry tons)	6,948.7	13,711.9	26.7	218.2	20,905.5
Disposal Methods Used			*Percent*		
Internal usage	24	28			26
Sold or given away	54	63	–	100	60
Waste disposal facility	22	10	100	--	14

[1] Standard industrial classification code.

Table 2 provides an example of the residue account for one industry type in a egion that was surveyed. Each of the other residue accounts is generated in tables of imilar construction.

Table 2.—Sample residue account for one industry[1]

Estimated amounts of wood fiber residues (dry tons)		
Residue	Survey amount	Population estimation
ood fines	10.46	18.31
dge/trim	415.50	727.13
hips	1.20	2.10
aper	0.00	0.00
allets	0.00	0.00
awdust	1,666.99	2,917.23
mbs	0.00	0.00
ark	409.50	716.63
isc. board	0.00	0.00
ther	1,638.00	2,866.50
ontaminated	0.00	0.00
	Estimated Disposal Amounts	
ternal usage	0.00	0.00
old or given away	3,638.25	6,366.94
aste disposal facility	503.40	880.95
timated total amount	4,141.65	7,247.89

[1]*Survey statistics:*

Net sent	7	Percent sample	100.00
Net return	4	Percent return	57.14
Population correction factor			1.75

UTILIZATION OF FIBREST

A mail survey of 600 wood-using industries in three central Massachusetts counties (hich included 69 cities and towns) provided a practical test for the FIBREST sstem.

Results tabulated by FIBREST indicated an estimated amount of 679,000 cy tons of wood fiber residues calculated from a 27 percent return of the two-page cestionnaire. Interestingly, 68 percent of that amount was contaminated, having been gherated by wrecking and demolition firms in the region.

Soon after this test, a private concern in the area, seeking to burn clean residues in pice of fossil fuels, conducted its own survey to determine the availability of uncontninated waste wood. The findings closely paralleled those figures generated by FBREST in the uncontaminated categories (Johnson 1977).

To the potential user of wood residues, FIBREST provides the opportunity to aess more accurately the availability of the resource. By tabulating, locating, and

describing the amounts of waste wood in an area as well as noting its current disposition, the user will be better equipped to make decisions on what is, normally, a marginal resource. With these capabilities, the system can be used for individual assessments of the residue situation. Or, with its flexibility of reporting modes and conversion parameters, it could be used to compare different waste wood inventories.

In conclusion, a note of caution is in order. For any inventory, the degree of accuracy desired (in the measurement and reporting of data) is directly dependent upon considerations of cost and scope. If estimates of wood residue amounts are used in FIBREST, then only extensions of those estimates will be reported.

As the potential of residues becomes more widely recognized and their need as a resource more acute, waste wood measurements should become more than just estimates. Only then will FIBREST, and other systems like it, be precise tools for resource management.

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COMPOSITION OF LANDFILLED URBAN WASTE RESIDUES

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Abstract.–Purpose of the study was to determine various quantities of wood waste being landfilled in the Atlanta metropolitan area. A survey was completed during the summers of 1977 and 1978. Information collected emphasized a large volume of potentially useful urban wood residue that was being wasted.

Landfill surveys were conducted by the Georgia Forestry Commission in th summer of 1977 and again in the summer of 1978. The majority of the landfills wa located in the Atlanta metropolitan area and a smaller number in the cities of Rom and Macon, Georgia.

The Atlanta area has increased rapidly in population and land use in the la decade. Correspondingly, there has been an increased volume of solid waste going t landfills and other disposal sites. An integral part of this waste stream is waste wood all types.

New emphasis is being placed on reducing waste and recycling materials wheneve possible. Since waste volumes have grown, resource potentials have increased.

Reuse can also lessen disposal and landfill problems. Disposal problems for woo residue are greatest in urban areas because a dense population and high industrial co centration generate great amounts of waste wood.

Disposal expense, environmental regulations, lack of disposal space, and a growin demand for wood products create an ever-increasing need to recycle or reuse thos heretofore discarded materials.

With the growing interest in energy and recycling, the Forestry Commissio became involved in determining the volumes of various wood products going into are landfills. A total of 22 landfills was surveyed by commission personnel to determin the relative amounts of various wood products.

This wood comes basically in two forms. Manufactured items, such as furnitur crates, pallets, and various manufacturing wastes, represent approximately one-hal the wood residue being landfilled in the Atlanta area, according to our study result (fig. 1). Raw wood (stumps, tree trunks, limbs, and leaves) make up the other compo nent (fig. 2). This amount does not include the vast quantities of paper packaging tha is discarded in the area.

The survey was conducted by stationing an individual at each landfill for a 1-wee period, typically from 8:00 a.m. until 6:00 p.m., Monday through Friday; howeve hours varied and several landfills were surveyed on Saturdays also.

As might be expected, the quantity of wood residue and its overall compositio varied by day of the week and individual landfills (table 1). Some landfills wer

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Figure 1.–Discarded pallets are unloaded into landfill.

Table 1.–Measured weekly totals[1]

Type	Volume (cu. yd.)	%	Weight (tons)	%	Cords	%
Jıkwood	8,886.0	57.8	740.6	49.3	296.2	49.3
B sh	5,495.6	35.8	512.7	34.1	205.1	34.1
Rındwood	703.2	4.6	77.7	5.2	31.1	5.2
Stmps	179.9	1.2	135.0	9.0	54.0	9.0
Wbd chips	102.8	.6	36.5	2.4	14.6	2.4
otal	15,367.5	100.0	1,502.5	100.0	601.0	100.0

[1] All tables compiled by Dale Higdon from data collected during the summer of 1977. During th period a total of 22 landfills was surveyed. These measurements included both government and prate landfills.

loıted near manufacturing plants that generated large volumes of waste wood, such as dcr trimmings, edgings, and sawdust. Others would receive packing crates, pallets, ar other shipping containers. Still other landfills, which catered to residential customer would receive a large amount of tree waste in the form of trimmings, stumps, etc.

At most landfills, the material was brought in by truck, weighed, and then taken to he dump site. At the remaining landfills, it was dumped without being weighed. In

Figure 2. Typical wood residue generated in the residential areas of an Atlanta suburb.

these instances, dumping fees were based on truck volume, not weight. Truck siz varied from pickup loads to tractor-trailer loads hauling 50 cubic yards or more. Fo commercial haulers, 25 to 40 cubic-yard loads were the most common.

The final dumping of the wood residue was of two general types. One mixed th wood indiscriminately with the other waste, such as household garbage, plastic, et This method was by far the most common since the primary purpose was to bury a the residue in as small a space as possible. Most commercial landfill operators did no have any facilities for recycling.

The second method was a separation type, where all wood residue went to separate site from other waste and garbage. Only two landfills were operated by th method, both of which were county government operations. The advantage of th particular system was that it allowed the separation of usable wood materials, such

ewood, specialty packing crates, etc., without posing a hazard to equipment oper-on or violating regulations.

This second method required additional work for the hauler, for foreign materials, ch as metal, wire, and garbage, had to be separated from the wood to be dumped. e other alternative is to haul only wood products on each load, a method that rked particularly well for government crews that hauled debris while another truck ked up garbage from households. Tree service companies also benefited since they ul loads composed mostly of wood.

To obtain weights of the various components of wood debris (brush, roundwood, imps, chips, junkwood, etc.), each load of material was weighed and its volume termined by measurement. From this, an average weight per cubic yard was calcu-ed for each type of wood waste. Based upon the data of this type collected from the o landfills with weight scales, conversions were possible for the remaining landfills ere only volume measurements were obtained. A correlation between weight and lume was drawn for each category (brush, roundwood, junkwood, stumps) and ecies (tables 2 and 3).

Volumes were converted to cords, using weight as a factor. An average cord ighs 5,000 pounds, or 2.5 tons. In converting stumps to cords, 90 cubic feet were ed. Cords from wood chips were figured, using 190 cubic feet per cord (table 4).

It should be noted that since the majority of field observations was taken during summer months, leaves remained attached to the brush. This factor obviously counts for some weight that would not be encountered in the winter months.

Further, it was assumed that due to adverse weather conditions in winter, the w of wood residue will result in greater variability than that encountered during summer. Ice storms, working conditions, etc., all have an immediate effect upon amount of residue hauled.

Table 2.—Species composition

Species	Volume (cu. yd.)	%	Cords	%
i	5,905.3	38.4	230.8	38.4
dwood	9,462.2	61.6	370.2	61.6
otal	15,367.5	100.0	601.0	100.0

Table 3.—Category of classification

Category	Volume (cu. yd.)	%	Weight (tons)	%	Cords	%
Tree parts[1]	6,378.7	41.6	725.4	48.3	290.2	48.3
Junkwood	8,886.0	57.8	740.6	49.3	296.2	49.3
Wood chips	102.8	.6	36.5	2.4	14.6	2.4
Total	15,367.5	100.0	1,502.5	100.0	601.0	100.0

[1] Brush + roundwood + stumps.

Table 4.—Assumptions

Brush	:	Average weight per cubic yard	=	186.6 lbs.
Roundwood	:	Average weight per cubic yard	=	221.1 lbs.
Junkwood	:	Average weight per cubic yard	=	166.7 lbs.

5,000 lbs. (2.5 tons) per cord

Wood chips	=	190 cubic feet per cord
Stumps	=	90 cubic feet per cord

Weight of wood chips and stumps = No. cords × 2.5 tons

SOURCE SEPARATION–PROCEDURES AND PRACTICES

Millard C. Davis[1]

Abstract.–Urban programs in source separation of waste wood in New Jersey center economically on two types of programs, those which expect remuneration and those which do not. Those with a future tied only to the public-service aspect appear to have the greatest potential for survival.

Source separation programs in New Jersey are on the increase, from about 30 pro-rams reported in 1977 (U.S. Environ. Prot. Agency 1978) to over 130 municipally upported programs and an unknown number of private operations as of December 978. Until now the major impetus for these recycling efforts has been the drive of rivate individuals and groups. A fluctuating balance has, in most of the privately run rojects, been struck between the provider of recyclable or secondary materials and usinesses in the secondary materials market, with homeostat feedback loops keeping he system in equilibrium most of the time. Choosing one point of entry into this ircuit, to give an example, a group decides that it needs money, locates a market for ecyclables it might sell, collects the materials, and sells it to the market. If the market, he secondary materials merchant, can prosper very much by receiving these materials, t will offer a high price. If the market is down, the price will drop. Naturally the roup collecting the materials will tend to match its efforts to the strength of the iarket. In this way the market receives about what it needs and suppliers are repaid or their efforts.

In the case of municipally supported recycling programs, however, long-term ontracts between the supplier (the municipality) and the market (one or more col-ectors or secondary materials merchants) are being encouraged by the State of New ersey with floor prices and escalating clauses. Now the material will tend to have a eady flow rather than a fluctuating one.

This sort of program brings the significance of recyclables so much to the forefront f commerce that the use and continuing reuse of secondary materials is enhanced.

For New Jersey, the New Jersey Solid Waste Management Act (c.326, Laws of 975) and the Federal Resource Conservation and Recovery Act (P.L. 94-580; called CRA) operate to promulgate strong source-separation programs. The provisions of 326, which divide the State into 22 Solid Waste Management Districts (the 21 coun-es and the Hackensack Meadowlands District), require that each district, alone or intly with another, prepare a master plan for solid waste management. Each plan iust include an evaluation of possible programs in source separation, with the first lans required to be submitted to the Commissioner of the Department of Environ-iental Protection by July 26, 1979, and the last ones by January 24, 1980. Source paration of urban waste wood will be given impetus by the support given to recyc-

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ling in New Jersey, which a number of sources have begun dubbing "the Recyc State."

How much waste wood is available from municipal solid waste? According to "Fourth Report to Congress: Resource Recovery and Waste Reduction" (U.S. Envi Prot. Agency 1977) in 1975, 1.8 million tons of wood packaging were discarded f post-consumer and commercial solid waste sources; not even 1,000 tons were repo as recycled. Of yard wastes, 26.01 million tons were discarded, and again not e 1,000 tons were recycled. Many tons of each probably were recycled, but the r tively minute figures were dropped during the production of massive accounting. W remains as significant is the general lack of commitment to recycling of waste wo much less commitment to strong municipal source-separation programs, efforts wh are economic and environmental answers to economic problems.

In New Jersey the hard economics are that, while we have over 300 land (serving 567 municipalities as well as the other generators of solid waste), many rapidly nearing capacity and others will be phased out as not meeting the "sani landfill" definitions of RCRA. Into these landfills in 1977 went 465,348 cubic y of vegetative wastes. Most of that probably arrived in the form of leaves, but str municipal composting programs could have significantly reduced that figure wh both leaves and wood were picked up for composting. In Camden County du 1977, about 19,012 tons of tree and landscaping refuse were collected from 30 (ou a possible 37) reporting municipalities. So tight has the situation become there while in 1976 the county landfills served 81 percent of the population, by the be ning of 1978 only about 34 percent (or about 146,758 tons) of the county's t solid waste was being shipped to landfills elsewhere (Camden County (N.J.) S Waste Advis. Counc. 1978).

While tree and landscaping refuse does not play a great role in the total munic refuse picture (about 4 percent), even a modest source-separation program could l in that county. Neighboring counties have shown increasing resistance to filling t landfills from Camden's overflow.

As the New Jersey district master plans are submitted, feasible source-separa programs will obviously be looked upon with great favor by the State review agencies. Efforts in urban waste wood utilization can look forward to a strong posi response from the Solid Waste Administration.

What is being done currently by municipalities in the way of source-separa programs? Two types of programs seem popular.

A. In the first type the cost of the operation is borne by the agency, with direct remuneration. A savings is reckoned from the potential cost of only other considered alternative—landfilling. Four examples stand out:

1. Collection of trees, most notably Christmas trees, by the municipality ar free return of them to the public as chips. Usually the trees and/or other wood dues are picked up at curbside, transported to a municipal site, chipped, and t dumped as chips at a public site on a designated day for the citizens to come collect.

In one municipality of nearly 70,000 people, an estimated 750 yards of com-icted Christmas trees were last year returned to the public as 180 yards of chips. The ıly constraint placed upon people coming to collect, which was done in the parking t of a local high school on two Saturday mornings, was that they take away no more an four containers worth; no one monitored this closely however. Fifty yards were ft over, and these went for municipal mulching needs. The cost to the town was esti-ated at about $200. This amount was figured on the saving of dumping costs (about ,200), minus labor and other direct costs, as well as those associated with owning vo chippers, valued at about $5,700 each, which are able to cut sections of wood feet by 3 inches in 1 second, large ones taking longer. Such a service has been oper-ing for 4 to 5 years.

2. Another municipality of about 58,000 people includes free 2-foot lengths of ewood in its program. Both chips (cut up by two municipal chippers) and firewood e derived from trees and branches collected throughout the year and are stored at e end of a dead-end street where people can come for them any time. Some of the ips are used by the municipality itself, as mulch in parks, etc., and some of the fire-ood is used in one of the maintenance buildings, which is heated solely by a wood ove. Christmas trees play no role in either aspect of this program, for they are picked by a private collector.

3. In the case of a County Park Commission, trees are collected if there is enough a load; otherwise, people are welcome to drop them off themselves. About 2,100 ristmas trees were acquired under this program last year. All the trees or parts ereof are chipped by the park, stored until spring, and then used as mulch in orna-ental beds and around the Commission buildings.

4. In still a fourth situation, a municipality of about 110,000 people collects trees d branches (as available or necessary) and chips them. Some of the chips are used by e municipality itself as mulch; the rest are unloaded onto State property, from which e State takes them for use in parks and elsewhere.

B. In the second type of source-separation program, there is some direct return on the investment by making direct sales of chips and/or firewood to individuals. Here three cases will suffice:

1. For 8 years a pair of municipalities, with populations of about 20,000 and 000, has cooperated in a broad-scale source-separation program, part of which has cluded Christmas trees. The program began as far back as 1970-71 with volunteers om the community and members of the civic environmental committees, which soon cluded members of the municipal Environmental Commission. From December 1971 ward, township sanitation crews were provided to handle curbside newspaper collec-on and to maintain the six recycling stations; in addition, there was some private rbside collection on the monthly basis under a contract which stipulated a return of percent of the income from sale of the newspaper. Heavy use was made of remind-s via local newspapers, community letters and notices, radio station broadcasts, sters, and displays. Guidebooks and programs for schools were available, and many mmunity groups (ecology committees, school students, scouts, League of Women oters, Welcome Wagon, etc.) pitched in. The intake was annually: 250 tons of waste

newspapers, 125 tons of glass, 60 tons of tin and aluminum, 500 to 1,200 old t phone books, 3 to 4 truckloads of "old but still usable" household items for Rescue Mission, and 1,000 Christmas trees recycled into mulch and sold to reside The average annual profit for the town of 20,000 people was considered to be ab $3,000. Figures for 1975 show a slight loss in the Christmas tree program. One th sand Christmas trees were chipped and placed in 560 bags as mulch, then sold at per bag, resulting in an income of $140. The township saved an estimated $46 in la fill and trucking costs. The chipper was paid $221. The loss of $35, however, obviously absorbed in the overall gains from the program.

The curbside recycling program has recently been dropped, and with it went wood source-separation project. At present, bins are available at two sites for peo to bring in newspapers and glass, separated by color, which are picked up by a priv collector. The Christmas trees are picked up by the municipality and dumped in a se wooded area.

2. In another municipality of about 45,000 people, located in the most indust part of New Jersey, tree cuttings alone are sold. They are offered on Saturday mo ings between 8 a.m. and 1 p.m., primarily from November to March, at 10¢ per pie with only 30 pieces allowed to be taken away per car. This year more was sold t ever before. The program costs the town more than it makes, primarily for the la of three or four men splitting wood. Though the going price of the wood section only one-half that of local commercial prices, not enough is sold here to draw co plaints. Still, the temptation to steal is reduced by piling the wood in a fenced-in ar behind a park.

Although this municipality has a strong curbside source-separation program f used newspaper and glass, the operation for wood is kept separate.

3. Another municipality of about 25,000 people in the same general area has slightly more structured price system. Here cordwood is sold by the rick ($5), quar cord ($10), half-cord ($20), and full cord ($36). Unfortunately, since the woo stored openly, most of it is stolen. As a result, splitting is delayed until the selling t in October. This program is viewed as perhaps more of a liability than an asset beca of the number of serious injuries which occur to municipal employees during splitt which is done by a machine.

What supports apparently successful municipal programs in source separatior waste wood?

1. Putting the program on a public service basis where there is no attempt create a money-making operation. Most so-called recycling programs try to appea economically self-supporting, even as profit-making. Rises and crashes are frequ and, as a result, entry into such programs is often considered as political death elected officials.

2. Results which reach into another area, especially a nonessential but forwa looking one. In one municipality, wood chips are not only distributed to parks around municipal buildings, as well as to the public, but at least one official consic them potentially useful in helping condition soil in an area which is being left "natur

entially as a municipal wild preserve. This person also sees value in allowing the final ver on landfills to go wild, establishing wild parks.

What can bring down urban wood programs?

1. Being tied to another program which, while presently very promising in one ce, has a history of fluctuating success elsewhere. While recycling industries in New sey appear to be in excellent health, municipal programs in source separation have enough ups and downs to render them uncertain bases, unless perhaps the whole ycling effort is declared a public service, or even associated with a national necessity broad scope.

2. Failure to accomplish the plain mechanics successfully, such as handling ma-hery, in a way which results in accidents that mar the program.

In conclusion, not only do the requirements of the new solid-waste laws offer a lift to source-separation programs, but a new operation being considered by the nden County Shade Tree Commission may prove to be a way of increasing markets:

Trees, tree wastes, and wood products now contribute significantly to the prob-em. During the sixteen-year period between 1955 and 1971, over 120 million cubic eet of wood residues from land clearing were destroyed in New Jersey alone - nough lumber mass for the construction of some 37,000 average homes. These tatistics were compiled at a time when open burning was the accepted means of lisposal. With 1973 came the prohibition of this method, resulting in this inordi-ate amount of usable wood waste becoming a key component in the solid-waste lisposal dilemma.

The implementation of a Waste Wood Recycling Facility in Camden County hows great promise for helping to alleviate these conditions in the future. Waste vood heretofore earmarked for disposal can be rechanneled through the facility ither directly to the proposed Lakeland site, or indirectly through the establish-nent of four to six transfer stations strategically situated throughout the county.

At the facility itself, the material would be sorted first into a tree's component arts; i.e., tops, large branches, leaves, boles, stumps, etc. Next, further separations s to quality and/or species would be performed (a lumber mill might be interested n purchasing certain species of oaks for use in veneer production). A metal detector vould ensure against equipment damage due to hidden hardware within the tree. ower-quality logs would be cut into uniform lengths, to be split as firewood.

The Shade Tree Commission of Camden County, working in cooperation with e Camden County Municipal Utilities Authority, the N. J. Bureau of Forestry, nd Cook College, Rutgers University, has found a great potential use for wood hips produced at the facility in the City of Camden's Sewage Sludge Composting rogram. Under this program, wood chips are currently being purchased on a con-ractual basis from a major area land-clearing operation. The chips are combined vith dewatered sludge at a ratio of two parts chips to one part sludge, then stacked n composting piles and aerated to hasten the decomposition process. The end roduct is suitable for use especially as a growth medium for nurseries, and in slope tabilization. The participants in the program have expressed a great interest in

obtaining wood chips for this operation from the proposed Camden County facilit This program in particular is definitely a progressive step toward wise utilization two "waste" sources.

In addition, with procurement of a front-end loader equipped with power tak off (a necessity to all operational phases) and a single attachment, leaves fro municipal collection rounds can be stacked, aerated, and decomposed into a fi organic material perfectly suited for farm and garden soil enrichment. This mater could be made available to low- and moderate-income families who grow their ov food.

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DETERMINATION OF WOOD CONTENT IN DEMOLITION AND CONSTRUCTION WASTES

James A. Commins[1]

Abstract.—Demolition and construction waste streams were evaluated on a national basis by a unique combination of empirical and predictive techniques. National figures developed indicate 55 million total tons, the waste wood fraction of which is 22 million tons, representing 2 percent of the heating value of all U.S. coal production.

INTRODUCTION

Forty years ago the practice in demolition and construction was to save and sell used materials. In fact, many demolition and construction companies had a thriving business in used lumber. As labor costs increased and powerful wrecking equipment became available, hand-wrecking (which made possible the utilization of used lumber in new construction) became economically unfeasible. Today it is practically extinct. The wood fraction of demolition and construction waste is generally in shattered form, mixed with other debris, and disposed of at landfills.

Two factors have signaled the need to alter this process. Regulations on solid waste disposal were tightened, dramatically increasing the trucking distances to acceptable disposal sites and raising the dump fees because of increased site preparation and operating costs. During the same period, the United States got its first taste of energy shortages and much higher energy costs. These two factors—high disposal rates and high energy costs—are responsible for the interest in waste wood.

Prior to 1975, considerable work had been done in analyzing municipal household wastes and examining energy options. A fundamental knowledge for any production operation is the availability, quality (constituents in the case of waste streams), and cost of feedstocks on which to base production estimates. While such data were generally available in the case of municipal waste, no such comparable condition prevailed for demolition and construction waste.

In July 1976, EPA's Office of Solid Waste Management awarded to JACA Corporation a contract to determine the energy potential from construction and demolition waste. This work was completed in February 1977, and the final report issued in April of that year. I was the principal investigator for that work, which is the subject of this paper. The interest in this work might be not only with the findings, but also in the methodology applied, since it uses human estimates in an optimal balance between sampling and measurement error.

Before this study was conducted, there were only sketchy data on the wood fraction in demolition and construction wood wastes. What little data there were exhibited large variations, some 700 percent. The goal of the study, therefore, was to determine the flow and percentage of wood waste with a nominal predicted accuracy of ±30 percent.

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Predictive or empirical techniques might be used in determining the combu fraction of demolition and construction waste. Predictive techniques involve mining the composition of buildings presently being demolished on the basis of k edge of materials and quantities and construction techniques generally emp during the time of construction. Information concerning the age of structures d ished, as well as the number of razed units of each construction type, is emplo conjunction with information on number of buildings demolished, average numl cubic yards of waste generated per building, and the density of the waste per yard to yield the total number of tons of combustibles available.

There are limitations on predictive and empirical techniques. Those affecti predictive technique have been summarized in a report.[2] First, estimates of bu composition at demolition will incorporate errors since alterations, additions replacements take place after the building is constructed. Second, the set of bui being demolished is not a homogeneous combination of all types and sizes, and th of the computed content of the average building may differ significantly from being razed. Third, clean fill or waste not containing wood, metals, or plastics m short-circuited and never reach the dump site. Fourth, on many jobs, the demo contractor leaves any basement or foundation intact, and fills the basement nonwood waste from the structure. Any waste so diverted is not truly available part of predictive estimates.

Empirical sampling involves actual analysis of representative waste stream inferences made on the total, based on this sampling. It also has some drawb First, sampling involves the random selection of sites and times of observations often not possible to achieve this randomness because of time and budget constr To the extent that randomness is lacking, errors may enter into the estimation pr Second, measurement error is involved in making the empirical findings.

In this study we employed a combination of empirical and predictive techn to develop estimates of the annual amount of construction and demolition wast the fraction of that waste which is wood. Our study found that the United S annually produces 55 million tons of waste from demolition and construction ities; that waste wood accounts for 22 million tons (40 percent) of this total; tha waste wood has a heating value of 3.75×10^{14} BTU, or about 2 percent of the e derived from coal in this country annually. The amount of waste wood and its potential discarded by various cities is shown in table 1.

An important finding for the design of any waste-process facility that uses waste from demolition and construction activities is the bimodal distribution c wood content in the waste arriving at a landfill. A frequency distribution plot f loads was developed during training of field observers (discussed later). The same eral type of distribution occurred in field tests at 29 sites in 10 cities. This distrib has important implications for the design of a recovery facility since it affects st area, storage, and separation.

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[2]Wilson, David Gordon. 1976. An investigation of the potential for resource recovery demolition wastes. Mass. Inst. Technol.

le 1. Annual tons and BTU potential of wood waste from construction and demolition wastes of 10 cities in 1976

City	Thousand tons	BTU potential
adelphia	190	3.3×10^{12}
Angeles	670	11.0×10^{12}
ago	400	6.9×10^{12}
ston	110	1.9×10^{12}
oit	490	8.5×10^{12}
ni	67	1.1×10^{12}
ouis	230	4.0×10^{12}
nta	42	$.72 \times 10^{12}$
burgh	100	1.8×10^{12}
neapolis	67	1.2×10^{12}
verage	237	4.0×10^{12}
Total	2,366	39.9×10^{12}

METHODOLOGY

At the outset of the study, it was intended that the following equation would be d separately for demolition and construction waste to arrive at the number of tons combustible debris generated annually from demolition and construction activities:

$$\underset{(1)}{\frac{\text{Average yd}^3}{\text{building}}} \times \underset{(2)}{\frac{\text{tons}}{\text{yd}^3}} \times \underset{(3)}{\frac{\text{buildings demolished or constructed}}{\text{year}}}$$

$$\times \underset{(4)}{\%\ \text{combustible by weight}}$$

$$= \frac{\text{tons of combustible}}{\text{year}}$$

(1) was determined from primary data obtained from members of the demolition construction industries;

(2) was calculated from the weights of 30 sample truckloads of demolition waste 30 sample truckloads of construction waste of known volumes;

(3) was determined by extrapolation from the figure on total number of residential dings demolished in the United States, found in U.S. Bureau of Census Report C45, obtain an annual figure on all categories of residential, commercial, and industrial dings demolished. Extrapolation was based on the ratio of residential buildings structed or demolished to nonresidential buildings (commercial and industrial) structed or demolished. Data were derived from the annual building construction demolition permit records of the 10 cities visited. These calculations are based on

the number of buildings demolished or constructed after issuance of a permit; they not cover unpermitted operations. Unpermitted operations, which occur most ofte rural areas where levels of demolition activity are low, are expected to represe negligible part of the total activity.

(4) was obtained from statistical analysis of the data collected at disposal in Philadelphia, Los Angeles, Minneapolis, Houston, St. Louis, Miami, Pittsbu Chicago, Atlanta, and Detroit. A total of 29 disposal sites was visited and 1,001 t dumpings observed.

TRAINING

The data-collection methodology for part (4) of the equation used visual est tion to measure percentage of combustibles by weight. Therefore, special training instituted. The questions to be answered in the training phase were:

1. What were the best techniques for observing and estimating the volume of struction and demolition waste in a disposal operation?

2. What was the accuracy of the estimation?

3. Was the accuracy improved significantly by averaging the estimates of tw more observations?

A 6-week-training session was initiated during which these issues were addres It was conducted at a suburban Philadelphia disposal site licensed by the Stat Pennsylvania for demolition and construction waste. After meeting with site person several areas were designated and cleared so that the training loads could be kept s rate for future analysis. Arrangements were made with a local demolition tractor to have his incoming 50-cubic-yard trucks stop at a nearby scale to obtain g and tare weight for the vehicle. Trash bins of 12 to 18 cubic yards and a dump t were used in the separation of the wood fraction.

When a weighed truck pulled into the landfill area, the observers positioned th selves around the rear of the truck at safe distances and at unobstructed observa points. The best location proved to be about 30° from the rear centerline of the tr Observation of material was made while the load was dumped and after it was on ground to make an estimate of the amount of wood and wood products in the l Because this was a training exercise, estimates of the first loads were made on a vol basis until the observers developed a correlation between the volume and we percentages.

Estimates of weight, along with date, time, source, truck weights, and gen comments were recorded on a data sheet. All loads were photographed for subsequ analysis (fig. 1).

Four JACA employees went through the training program. Two had col degrees, and two were technicians with several years experience. It was not kn how many loads would be required to develop an acceptable degree of accuracy percent). Progress was monitored and terminated at 32 loads, when accuracy satisfactory.

The loads were hand-separated into wood and nonwood piles. Portable t dumpsters and a dump truck were used to transport the separated materials bac

Figure 1.—An unseparated load of demolition waste with a high percentage of wood.

ie scale. Because of the size and weight of some of the beams and concrete blocks, a ont-end loader was occasionally used as an aid in loading the receptacle. Since the ebris was often very small at the bottom of the pile (these smaller pieces were often ound up when the front-end loader raked the pile), the weight percentages of the maining 10 percent or less were often estimated and added to the weigh-ticket itals. The estimated remainder was less than 200 pounds. All of the debris came om the Philadelphia area; information about the type of structure from which it iginated was obtained from the drivers or dispatcher.

The actual percentage of combustibles was obtained in the following manner:

Percent combustibles

$$= \left(\frac{\text{gross weight of separated materials}}{\text{gross weight of incoming truck}}\right)\left(\frac{\text{weight of container}}{\text{weight of truck}}\right) \times 100$$

Thirty-two loads of demolition waste were hand-separated and weighed during e training period. It was noted that demolition loads tend to occur most frequently ith high-percentage combustibles or low-percentage combustibles rather than in the iddle range. This same condition prevailed in 1,001 observations in later fieldwork.

The sampling process is subject to two types of errors. The measurement or onsampling error occurs because of a difference between the actual value and the easured value; this kind of error arises from factors such as imperfect observation, ulty questionnaires, or inaccurate tallying. The sampling error results from the chance lection of sampling units; this error occurs when a partial observation of the universe

takes place. If the entire universe were studied, the sampling error would be zero.

The total error in a statistical survey such as this one is the sum of the mea ment error and the sampling error. The major concern is to minimize the total e Reduction of the measurement error is achieved by defining precisely the popula to be studied and its traits, by refining the measurement process to the highest de and by training the individuals doing the measurement as thoroughly as practic These precautionary measures are usually costly, leading to the necessity of using s samples. However, small samples tend to have larger sampling errors. Therefore, t are two options available: the sample size can be kept small and the measurer made in a sophisticated manner, or the sample size can be large and the measurer made in an unsophisticated manner. The following example should help illustrate method of estimating the percentage of combustibles in construction and demoli waste. Assume that a sophisticated measurement process would limit the sample to 50 observations; an unsophisticated technique would employ trained observe estimate the combustible proportion and would allow for a sample size of 300 ol vations. Assume that the measurement error in the first case would be 5 percent ar the second case 10 percent. In estimating proportions, the formula for the maxi sampling error is given by:

$$(1) \quad \delta = z\sqrt{\frac{\pi\,(1-\pi)}{n}}$$

δ = sampling

z = normal curve deviate, which is determined by the level of confidence

π = universe proportion being estimated

In the absence of information concerning the possible size of π, it is assign value of ½, which maximizes the expression $\pi(1-\pi)$, and, therefore, maximizes δ given level of confidence and sample size. In the cases cited above, if a level of co dence of 90 percent is employed:

$$(2) \quad \delta_{90} = 1.645\sqrt{\frac{(.5)\,(1-.5)}{50}} = .116$$

$$\delta_{90} = 1.645\sqrt{\frac{(.5)\,(1-.5)}{300}} = .047$$

Using a level of confidence of 95 percent:

$$(3) \quad \delta_{95} = 1.96\sqrt{\frac{(.5)\,(1-.5)}{50}} = .139$$

$$\delta_{95} = 1.96\sqrt{\frac{(.5)\,(1-.5)}{300}} = .056$$

nce:

Total error = Sampling + Measurement error, the following results are obtained with 90 percent confidence:

Case 1 Total error = .166 + .05 = .165
Case 2 Total error = .047 + .10 = .147

ith 95 percent confidence:

Case 1 Total error = .139 + .05 = .189
Case 2 Total error = .056 + .10 = .156

At both levels of confidence, the total error is smaller when the sample size is creased at the expense of a larger measurement error. In the case of this study, we ose the option of increasing the sample size as opposed to reducing the measurement ror, and the cost of doing so was significantly less than reducing the measurement ror.

STRATIFYING THE SAMPLE

In stratified random sampling, the universe is classified into mutually exclusive bgroups or "strata" and samples are drawn from each of them. Sample statistics are lculated from each of these strata and are combined to yield an overall estimate of a pulation parameter. The basic purposes of stratified sampling, as compared to simple ndom sampling, are to obtain a sample that closely resembles the universe from hich it was drawn and to reduce sampling errors. These objectives are accomplished grouping together into strata those elements which are more alike with respect to e characteristic under investigation than are elements in the universe as a whole. ratification is most effective when the elements within strata are as homogeneous possible, as regards the property to be studied, and the differences among strata are great as possible.

In this study, the demolition samples were to be stratified by type of structure. itially, four strata were contemplated: residential, multi-unit residential, commercial, d industrial buildings. Experience in the field led to a reduction in the number of rata to two: residential and other. This reduction was made because many cities did t distinguish among the various types of structures, or because the required number observations to define strata was not generated in each of the four areas. The same rata were initially proposed for the construction data. The number here was also duced to two for the same reasons. The stratification by phase of construction was so considered but was abandoned after attempts to gather the data proved highly practical within budget and time limitations.

In determining the geographical sites, the United States was divided into four areas d a percentage of the total population calculated for each area. This technique sulted in a selection of cities that would represent any regional peculiarities of ilding material and techniques. Ten cities were selected on this area breakdown on e basis of construction and demolition activity. Within each of these 10 cities, sposal sites were chosen on the basis of activity at the site and the willingness of the erator to cooperate by allowing field technicians to make observations.

Once the cities had been selected, the desired number of observations in e stratum (residential and other) for construction and demolition was determined averaging the number of construction and demolition permits issued in each during the period 1970-75. These permits were used to establish the ratio of resic tial to other units constructed or demolished. This ratio was then applied to number 30, the desired number of observations for each city, to determine the desi number of observations in each of the two strata for that city.

Teams of two technicians each were sent to disposal sites in each of the 10 cit Each technician independently observed loads as they were dumped, and the indi ual readings were averaged to obtain a better estimate of the percentage of comb ibles. Varying lengths of time were spent in an effort to gather enough data to m the desired stratification, which was universally met.

Since the observed samples exceeded the required number at each locatior weighting technique was devised to allow the use of all the data generated, even wh the actual number observed exceeded the desired number. Weights were assignec such a way as to keep the strata in the proper desired ratio. The weighted techni calculated the percentage combustible for each city as the weighted mean of the t strata, employing the desired number of observations in each stratum as weights.

To determine the overall percentage combustibles, the arithmetic mean a standard deviation of the 10 weighted percent combustibles were calculated. Empl ing this datum, a confidence interval for the overall percentage of combustibles w calculated as follows:

$$\bar{X}p - t_{.05}\,(s/n) \leqslant \frac{95\%}{Mp} \leqslant \bar{X}p + t_{.05}\,(s/n)$$

where:

$\bar{X}p$	=	mean of the 10 weighted percent combustibles
s	=	standard deviation of the 10 weighted percent combustibles
$t_{.05}$	=	coefficient, which is determined by the level of confidence
n	=	sample size (10)
Mp	=	mean percent combustible for the universe.

For demolition $s = 12.12$

$$38.60 - 2.262\left(\frac{12.12}{3.16}\right) \leqslant Mp \leqslant 38.60 + 2.262\left(\frac{12.12}{3.16}\right)$$

$$29.92 \leqslant Mp \leqslant 47.28$$

For construction $s = 8.34$

$$47.59 - 2.262\left(\frac{8.34}{3.16}\right) \leqslant Mp \leqslant 47.59 + 2.262\left(\frac{8.34}{3.16}\right)$$

$$41.62 \leqslant Mp \leqslant 53.56$$

This interpretation of the confidence interval is as follows: there is 95 percent ertainty that the mean percentage combustible of all demolition waste is between 9.92 and 47.28 percent. The calculation of the percentage combustible of construc- ion waste and the interpretation of the resulting confidence interval is analogous to hat for demolition. Once the mean percentage combustible was determined, the total umber of tons of combustibles was calculated by employing this percentage in con- inction with data developed on the basis of predictive techniques. The calculation for emolition waste is:

$$TCD = A \cdot D \cdot B \cdot P$$

here:

TCD	=	total number of tons of combustibles per year from demolition waste
A	=	average number of cubic yards of waste per building
D	=	average density of demolition waste
B	=	number of buildings demolished per year
P	=	percent combustible of demolition waste

The average number of cubic yards per building was determined from a National ssociation of Demolition Contractors (NADC) cooperative questionnaire. The average ensity was determined in field experiments with JACA technicians. The number of uildings demolished per year was determined from literature searches.

In the case of construction waste, it was impossible to develop data from haulers ; to the average volume of loads from typical waste sites, as was done via the ques- onnaire for demolition waste. These data were not available because of the long dura- on of construction activity.

The calculation for construction waste differs significantly from that for demo- ion waste:

$$TCC = P \cdot W$$

iere:

TCC	=	total number of tons of combustibles per year from construction waste
P	=	percent of wood that is wasted in construction
W	=	total amount of wood consumed in building and construction

The percentage of wood that is wasted in construction was determined from formation gathered through literature searches and discussions with building con- actors based on their estimating procedures. The total amount of wood consumed is ken from existing government sources.

The primary segment of this study utilized field measurements of properly strati- ed samples. The plan was to use a total of at least 600 random samples from three es at each of the 10 cities visited. In the final analysis, 1,001 samples were obtained. is sample size was large enough to account fully for geographical differences in

building sites and to allow for different sizes and types of buildings. Trained observ were used to estimate the percentage of combustibles as the trucks dumped their loa A satisfactory measurement accuracy by this means would be 20 percent for all sam totals. The training showed that even higher accuracy was obtained. The objective each city studied was to collect enough samples (percentage combustible values) demolition and construction waste to meet the previously determined requirements each category of a 60-sample stratified set.

The first data collection was done in the Philadelphia area. The Annual Build Construction Reports for the years 1970–75 were obtained to determine the strat cation, in preparation for actual fieldwork. Construction and demolition permits the past 5 months were examined to determine the recent activity levels in ea stratum. The contractors whose names appeared frequently on these permits w contacted to determine which Philadelphia area landfill sites they were using a arrangements were made with landfill operators to station field observers at f local sites.

The activity in demolition and construction was extremely low during the ini data-collection phase when compared to the activity levels during the earlier train session. This difference indicated that the generation of demolition and construct waste was sporadic. As a result, the fieldwork was rescheduled to coincide with peri of high demolition and construction activity in order to get the most samples dur field visitations.

It was evident that a refinement in the scheduling of cities was extremely imp tant. Following discussions of our objectives with the NADC, Mr. Ron Dokell, Pr dent, offered the Association's assistance and, together with the Energy and Recycl Committee, provided assistance on our visits to the 10 cities. The NADC commit supplied names of local members who aided in scheduling fieldwork to coincide w high demolition activity. These contacts were also helpful in directing us to the la fills where most of the waste was being hauled.

Arrangements were made to visit three landfills at each of the 10 cities. Beca one of the determining factors as to where demolition and construction debris will dumped is the cost of hauling based on distance, the observation of three local si helped neutralize intra-city peculiarities in activity or in composition of waste.

The method of obtaining percentage combustible data followed the proced described in the training section. At safe observation points, each load of constructi and demolition debris was analyzed while being dumped and while on the ground estimate the percentage combustible by weight. The driver of the vehicle was qu tioned briefly as to what building category provided the waste.

Depending on activity levels in each city, observers spent 1 or 2 weeks on site, a in some instances had to return to a city to satisfy the stratification requirements. T stratification for the city was referred to periodically during the week to determ whether sufficient residential, commercial, and industrial loads were being sampl Photographs were taken at several dumping sites for future reference.

Construction activity evidenced at the 10 cities was mainly in the form of sm truckloads and portable bins of wastes generated in renovation, roofing, and sid

rojects. Very little waste was observed from new building construction. One explaation for this phenomenon is that waste generated on construction projects is disosed of on the site to avoid paying dumping fees at a landfill. Therefore, it was necesry to schedule return visits to obtain fully stratified, 60-sample sets of construction mples.

Some of the city building reports did not distinguish between commercial and dustrial demolitions. Therefore, these two categories were combined into "nonresintial" construction and demolition for all the cities surveyed. Decreasing the numr of strata did alleviate some of the problems in obtaining a proper sample. After the ta on the 10 cities were reviewed, it was necessary to return to Miami, St. Louis, and hicago for sufficient data on construction. Sufficient demolition data were collected all 10 cities on the first visit because the demolition volume to building volume ratio so large that continual landfill dumping is necessary.

Individual observers' estimates were averaged at each of the 10 cities, and the fference between one observer's average for the entire sample and the average of two servers for the entire sample was negligible. Therefore, one observer was sent to each the three cities where insufficient data had been collected on the first visit.

The field data results collected on percentage of combustibles in the 10 cities are bulated in table 2.

The density of the loads was a second piece of primary data to be obtained in the ld. During the initial training session, 32 loads of demolition waste were weighed d separated at a local landfill site. A value for the average density of demolition ste was needed. The concentration of the various components of demolition waste ch as wood, brick, concrete, and dirt) and the permitted road weight of a particular ckload help determine the density of the load and the volume to which the truck

Table 2.—Weighted percentage of wood in demolition and construction waste
—Field Data—

City	Wood demolition	Wood construction
	.... *Percent*	
iladelphia	41	42
s Angeles	63	48
icago	44	60
troit	42	43
uston	27	63
Louis	51	50
ami	37	43
tsburgh	27	36
lanta	20	40
nneapolis	34	51
erage weighted percent combustible	39	48

can be filled. Often a 50-cubic-yard-capacity demolition truck with high density con ponents may be filled to only 20 cubic yards; a truck with a high percentage of woo is generally filled to volume capacity. The average volume of 32 truckloads average 40 cubic yards.

When the average densities for the 32 truckloads were calculated, the value for th density of demolition waste was found to be 25 pounds per cubic foot. This figure wa considered accurate for this study because the percentage combustible values for th 32 training loads had good distributive representation from both low-percentage an high-percentage combustible loads.

In order to use the equation presented in the National and Area Estimates sectior a value for the average number of cubic yards of waste generated per type of buildin demolished or constructed was needed:

$$\frac{\text{Average yd}^3}{\text{(const./demo.)}} \times \frac{\text{tons}}{\text{yd}^3} \times \frac{\text{bldgs. (const./demo.)}}{\text{year}} \times \begin{matrix}\text{\% combustible}\\ \text{by weight}\end{matrix}$$

$$= \frac{\text{tons of combustible}}{\text{year}}$$

To determine the volume of waste generated in the demolition of buildings, th NADC cooperated with JACA Corporation in administering a response-card progran which supplied data collected by 17 volunteer members of NADC.

Respondents remained anonymous through a respondent numbering system, an the geographical distribution was statistically sound. One card was completed for eac demolition job. The information entered on the card included duration of job, type c building, number of units if residential, number of loads, and the truck size.

The NADC response-card program ran for approximately 3 months, yielding 20 responses from the 17 respondents. Following completion, cards were separate according to building category, and the average volume of waste per demolishe building was calculated for residential, commercial, and industrial buildings.

Average volume of waste per building

Residential	450 yd^3/bldg.
Commercial	2,022 yd^3/bldg.
Industrial	3,860 yd^3/bldg.
Overall	1,370 yd^3/bldg.

From other information included on the response cards, the average duration o a demolition job could also be determined.

Average duration of demolition job	(days)
Residential	3.87
Commercial	9.56
Industrial	14.7
Overall	6.92

Lengthy job duration, variation in methods of disposal of construction waste, and the inability of members of the hauling industry to provide average estimates of volume of waste generated by each construction job frustrated attempts to determine the volume of wood waste generated in the construction of a residential building, a commercial building, and an industrial building. Therefore, it became necessary to develop data on the basis of estimates made by construction contractors on the percentage of wood waste generated on their jobs. Contractors were requested to estimate the wood waste as a percentage of wood ordered for each construction job. The results of this survey of 20 contractors indicated that an average of 7.4 percent of wood delivered is wasted in the process of construction. The average was tested for significance by the following equation:

$$\bar{x}_w - t_{0.5}\left(\frac{s}{\sqrt{n}}\right) \leqslant \mu_w \leqslant \bar{x}_w + t_{.05}\left(\frac{s}{\sqrt{n}}\right)$$

At a 95 percent level of confidence, $5.28 \leqslant \mu_w \leqslant 9.52$.

TOTAL ANNUAL ESTIMATES

Annually, the U.S. Department of Commerce, Bureau of the Census, issues a report entitled "Housing Units Authorized for Demolition in Permit-Issuing Place." The report gives the total number of permits issued for demolition annually.

Using the figures presented for the number of housing units demolished in cities over 50,000 population (0.34 of total U.S. population, 1970 Census) as well as the cities' populations, a statistical evaluation was conducted to determine whether a linear relation existed between population and number of units demolished, using methods of linear regression analysis. The equation $y = -3.05 + 0.0018x$ was derived where y = number of units demolished and x = size of population. This equation explained 61 percent of the variation for this relation. Therefore, there would be a certain degree of error in pursuing the calculation of a total for demolition of housing units by this method.

While the above equation might be useful in predicting the amount of demolition for an area, a more reliable estimate was needed. Therefore, it was decided that the figures for U.S. total number of housing units demolished based on reports from permit-issuing places authorizing the demolition of one or more housing units would be used. The Bureau of the Census states that these annual figures are based on reports from areas which represent about 80 to 85 percent of the population and would therefore imply that these figures probably represent 95 percent of the total U.S. housing-unit-demolition rate.

To convert from units demolished per year to residential buildings demolished p
year, the average number of units per building demolished from the building reports
the 10 cities was calculated. This was found to be 1.4 units per building. To determ
the total residential and nonresidential buildings demolished per year, the ratio of re
dential to nonresidential buildings demolished per year in the 10 cities surveyed w
computed and averaged from their respective building construction and demoliti
reports. The following equation was used:

$$\frac{\text{No. of residential buildings demolished}}{\text{year}} \times \frac{1}{.803}$$

$$= \frac{\text{No. of residential and nonresidential buildings demolished}}{\text{year}}$$

$$87{,}123 \times \frac{1}{.803} = 108{,}497$$

To determine the total number of buildings constructed per year in the Uni
States, a similar approach was used. Using data on residential construction obtai
from the National Association of Homebuilders, the following procedure was used:

$$\frac{\text{Residential units constructed}}{\text{year}} \div \frac{\text{average units}}{\text{bldg. constructed}}$$

$$= \frac{\text{residential bldgs. constructed}}{\text{year}}$$

$$\frac{1{,}512{,}900}{1} \div 2.5 = 605{,}160$$

$$\frac{\text{Residential buildings constructed}}{\text{year}} \times \frac{1}{.724}$$

$$= \frac{\text{residential and nonresidential buildings constructed}}{\text{year}}$$

$$605{,}160 \times \frac{1}{.724} = 835{,}856$$

ESTIMATING ENERGY POTENTIAL

The heating value of wood was taken as 8,613 BTU's per pound. By multiplying the tons of combustibles generated annually from these two sources, the energy potential of the waste wood can be calculated on a national level:

Demolition:

$$\frac{\text{avg. yd}^3}{\text{bldg.}} \times \frac{\text{tons}}{\text{yd}^3} \times \frac{\text{bldgs. demo.}}{\text{year}} \times \%\text{ combustible} \times \frac{\text{BTU's}}{\text{ton}}$$

$$= \frac{\text{total BTU's}}{\text{year}}$$

$$1{,}369.8 \times .337 \times 108{,}500 \times .386 \times (1.72 \times 10^7)$$

$$= \frac{3.3 \times 10^{14}\text{ BTU's}}{\text{year}}$$

Construction:

$$\text{Tons of wood consumed annually by construction industry}$$

$$\times \text{ average \% wasted per job in construction} \times \frac{\text{BTU's}}{\text{ton}}$$

$$= \frac{\text{Total BTU's}}{\text{year}}$$

$$35{,}000{,}000 \times .074 \times (1.72 \times 10^7)$$

$$= \frac{4.5 \times 10^{13}\text{ BTU's}}{\text{year}}$$

Total energy potential from demolition and construction nationwide

$$= \frac{3.75 \times 10^{14}\text{ BTU's}}{\text{year}}$$

To determine the energy potential from demolition waste for a given local area, the above equation is used with a substitution of number of buildings demolished per year within the city for the number of buildings demolished on the national level. The local weighted percent combustible figure can be substituted for the national average of 39 percent. The volume per building must be recalculated in accordance with the average ratio of residential, commercial, and industrial buildings indicated in the building reports.

To calculate the energy potential available from construction waste on a lo level, the amount of wood consumed must be estimated. The method used was to up an equality which relates amount of wood consumed by the construction indust on a given level to the number of buildings constructed on that level.

$$\frac{\text{Wood consumption nationwide, by construction industry}}{\text{buildings constructed nationwide}}$$

$$= \frac{\text{Wood consumption, by city, by construction industry}}{\text{buildings constructed, by city}}$$

$$\text{e.g., Chicago} \quad \frac{35{,}000{,}000 \text{ tons}}{835{,}856 \text{ bldgs.}} = \frac{x}{2{,}482}$$

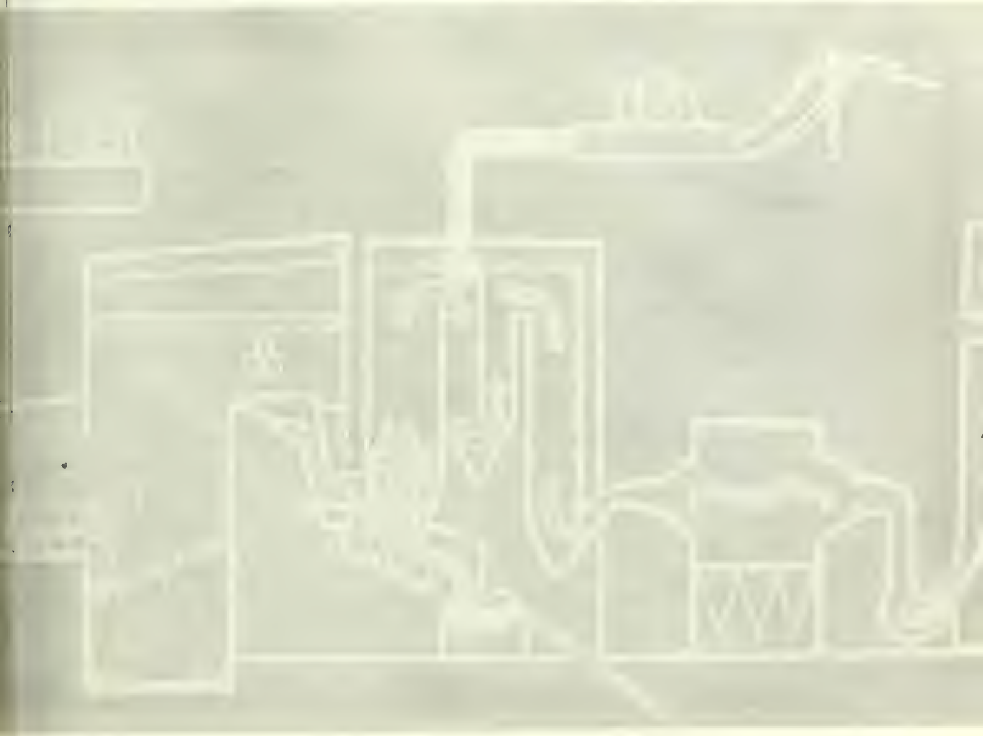
x = wood consumption = 104,000 tons per year, by Chicago constructi industry

Using the construction waste energy potential equation:

$$104{,}400 \times .074 \times (1.72 \times 10^{7}) = \frac{1.3 \times 10^{11} \text{ BTU's}}{\text{year}}$$

These equations may be applied to any locality that has the appropriate d available.

TOPIC II
UTILIZATION OPTIONS



PAPER FROM MUNICIPAL TREES

David F. DeVoto[1]

Abstract.—Because they encountered increasing numbers of trees killed by Dutch elm disease, the cities of Minneapolis and St. Paul attempted to find a method for wood disposal other than burning and/or burying in landfills. A large-size chipper seemed to be the solution to the problem.

THE NEED

A fungus (Ceratocystis ulmi) implanted in elm trees by bark beetles causes condition called Dutch elm disease. This disease has become extremely serious in th cities of Minneapolis and St. Paul over the last few years. Beginning in 1961 in St. Pau and 1963 in Minneapolis, the disease plodded along without causing real problem until about 1975, when the number of infected trees began to soar, as is shown i figure 1.

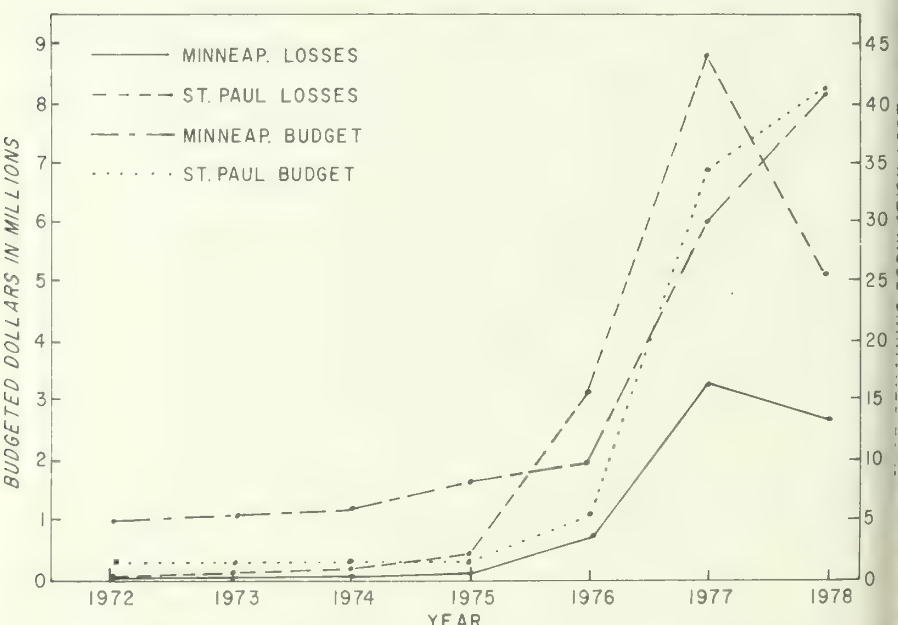


Figure 1.—Budgets and tree losses for Minneapolis and St. Paul.

[1]Director of Forestry, Minneapolis Park and Recreation Board, 250 South Fourth Stre Minneapolis, Minnesota 55415.

In the early seventies, realizing that losses were going to become high and that ollars for control were going to be limited, the cities (first independently, and then ter realizing they were following parallel paths, jointly) began trying to find means disposing of trees more efficiently. Until this point, trees were either burned or uried in commercial landfills. These methods were, even with low losses, not the best eans for disposal. As losses increased, they became even less acceptable.

In any large metropolitan area, landfill space is scarce and should be reserved for ousehold and industrial wastes rather than being quickly used up by tree brush and gs. When we discussed the possibility of bringing the large anticipated volumes to his e, one landfill operator said that he would only take our debris if we supplied a ton covering sand for every ton of material we dumped; this obviously would become pensive.

The other means of disposal available was open burning. With air pollution standds becoming more stringent, with increasing amounts of pollutants being generated thin cities, and with urban sprawl pushing suitable sites farther away, burning fell ort of being a good alternative.

In both of the above methods, another problem became clear. Large increases in lumes meant more equipment would be necessary, causing more capital investment. oney for this had to be borrowed at increasing interest rates. More labor had to be ed at even higher salary rates. The dilemma became worse.

Table 1.–Comparative disposal costs/ton

Year	1976	1977	1978
		Dollars	
Ldfill	4.25	6.00	7.20
Bning site	N/A	2.00	3.00

ALTERNATIVES

The most obvious alternative for a forester was to turn these costly-to-dispose-of ls into usable wood, which made sense because the wood was still sound. Its quality a structure were unchanged, and many of the logs were long and clear of limbs and kots. With the number of logs steadily increasing, it might even be feasible to move a sa mill into the area.

Not so, according to the sawmill operators. In our efficient methods for preservaon of city trees we had created a major stumbling block. Whenever a tree began to delop decay, someone had been there to chip away the decay and plug the hole with ccrete and reinforcement rod. Whenever a severe storm split and damaged a tree, we we "Johnny-on-the-spot" to screw in lag hooks, attach chains and cables, and fasten inarge bolt-rods. We even went so far as to trace the bark around these fixtures so th the tree would neatly grow over them, making them almost invisible. An additial problem was that every housewife who planned a Saturday garage sale advertisd it by nailing a sign (using a tenpenny nail) to our trees.

We had anticipated some problems with foreign objects in trees, but we did not realize just how serious these problems would be. It would have been nice to do away with the disposal problem and its inherent costs and perhaps even get a little return by selling our logs to sawmills. The sawmill operators quickly and firmly let us know that they were not interested in our trees, even if we gave them away.

Another possibility was to not saw up the material, but to grind it into wood chips. There seemed to be many uses for chips. We had, in the past, been chipping small branches (up to 6 inches in diameter) right on the street with small trailer-mounted limb chippers. Much of this material was used as mulch around our newly planted trees and shrubs. Any material not needed for our own use was easily given away to homeowners for their use. Hardwood chips of the proper quality and size were being used by local manufacturers of roofing felt. Although paper companies were at first somewhat reluctant to use hardwood chips for pulp, we felt a market could be developed and, if debarked and properly processed, many of our logs could be disposed of in that industry.

Further study indicated that chipper plants were relatively inexpensive, costing \$½ million to \$¾ million (compared to the cost of setting up a sawmill: more than \$1.5 million). The amount of space necessary was also less, and the amount of waste would be extremely small if a wood "hog" were incorporated into the system to regrind bark and "overs-and-unders" into fuel material.

Since we did not want to go into the chipping business, our next task was to find someone in the private sector who would be willing to invest in building and operating such a system. Again we ran into problems. The private investors needed many guarantees to protect their investments. Could we guarantee a certain number of tons of chips delivered in relatively even amounts and for a specified number of years? If we could not fulfill the quota, who would be responsible for the difference in the expected profit? This was all taking place in 1973-74 and, of course, hindsight now shows us that certain of these guarantees could have been met. At the time, however, acting as a public agency dealing with the citizens' tax dollars, we could not make such commitments.

We were then at the spot that the "little red hen" (in the children's story) found herself. When she could not get any help she said, "Then I'll do it myself," and she did. Well, we did too but not quite so easily; we built a chipper plant ourselves. Since we were not in the chipping industry and therefore knew very little about it, we searched a lot of printed matter, talked to a great many individuals and finally (with considerable help from a consulting engineer) came up with what seemed to be a workable plan.

SITE SELECTION

It was determined that we would need about 10 acres of land for erecting the plant and to use for storage and handling of the material. Although vacant 10-acre sites are not very common in a metropolitan area, there were five locations that were feasible. Best of all, they were owned by various government agencies and could be used without the need to buy land. As usual, things did not go quite the way we would have liked.

Site number one (fig. 2) was the most convenient for both cities and was our first oice. It turned out, however, that the agency owning it had it set up as an indus-al development site. The owners needed a long-term lease and expected us to pay m for the revenue they would lose while it remained undeveloped. Since our whole ture needed to be done with a very tight budget, the costs incurred would have n entirely too high.

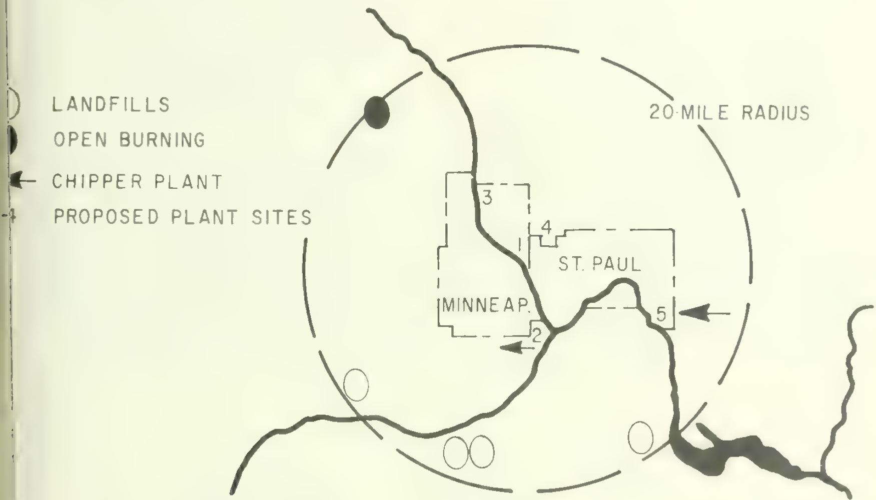


Figure 2.–Actual and proposed disposal sites in Minneapolis-St. Paul.

Site number two (fig. 2) was next best, but we found that it would be directly er the flight path of the airport. Dust from trucking and from the machinery ld create a hazard for landing aircraft. The metropolitan airport commission felt ngly that this would be an unsuitable location unless we would be willing to shut plant down during problem times. Since this would not be feasible, the next site considered.

This location (number three in fig. 2) appeared to be a good choice, even though eant a little farther hauling distance for St. Paul. It was located on property owned he City Water Department. No other use was foreseen for it, and it also had rail- access, which meant that if rail transportation of chips turned out to be our best hod, it would be inexpensive to put in a loading spur. Again, problems!

Use of the property required City Council approval. Just prior to our request, a ial-use permit had been given to a barge company to install a loading terminal on river just across from our proposed site. The Alderman for that ward had been eiving many complaints about loud noises due to barges being banged into each r night and day. He absolutely refused to allow anything to be done in that area might possibly make any noise.

Location number four (fig. 2) was convenient to both cities. It had enough space

and could receive Council approval. In closely examining the area, however, it v clear that interjecting many large trucks full of logs into an area of heavy traffic c gestion would become frustrating to all concerned.

Another area (number five in fig. 2) was finally selected to be used for the pla This area had certain drawbacks which caused it to be the last to be considered. primary concern was that it is within the "100 year" flood plain. Even though odds of flood were very small, machinery that would be affected by water would h to be made so it could be easily removed to high ground. The site was originall sanitary landfill, and soil borings from as deep as 60 feet were showing undecompo garbage, which meant that pilings would be required under equipment pads. Access the site was also somewhat constrained, and we realized that during spring thaw a heavy rains, we would be severely hampered by mud.

On the other hand, the site was on St. Paul Port Authority land, which we co use at no cost. It was remote from other land use except for a railroad-repair facility, cement plant, and a sewage-treatment facility. For this reason, there would be neighbor problems. If necessary, we could rather inexpensively put in a railroad s for shipping and possibly even set up for loading river barges.

PLANT COMPONENTS

While site selection was going on, we were also determining what compone were necessary for operation. It was decided that the best power to use was electi motors. Components (fig. 3) were as follows:

1. Nicholson 55- by 58-inch roto-drum chipper (fig. 4).
2. Precision No. P848M debarker, complete with control panel and motor star (fig. 5).

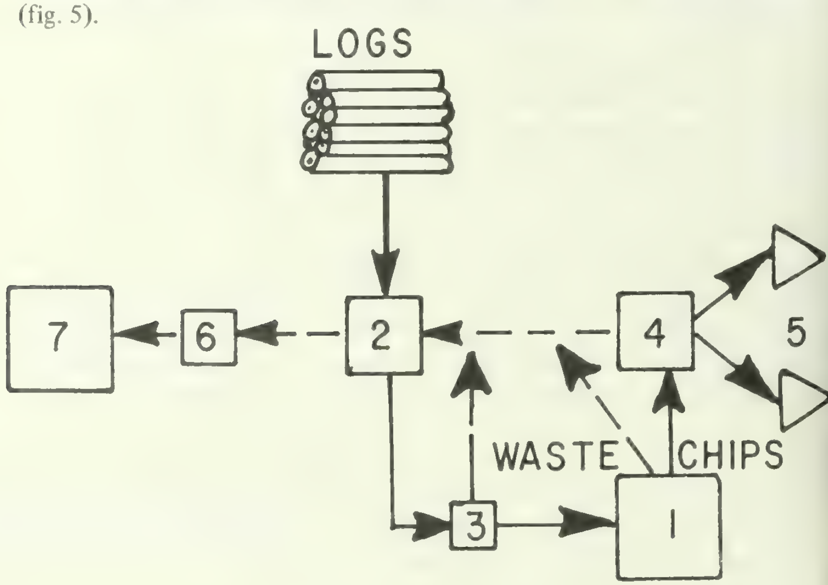


Figure 3.–Components of the chipping plant.

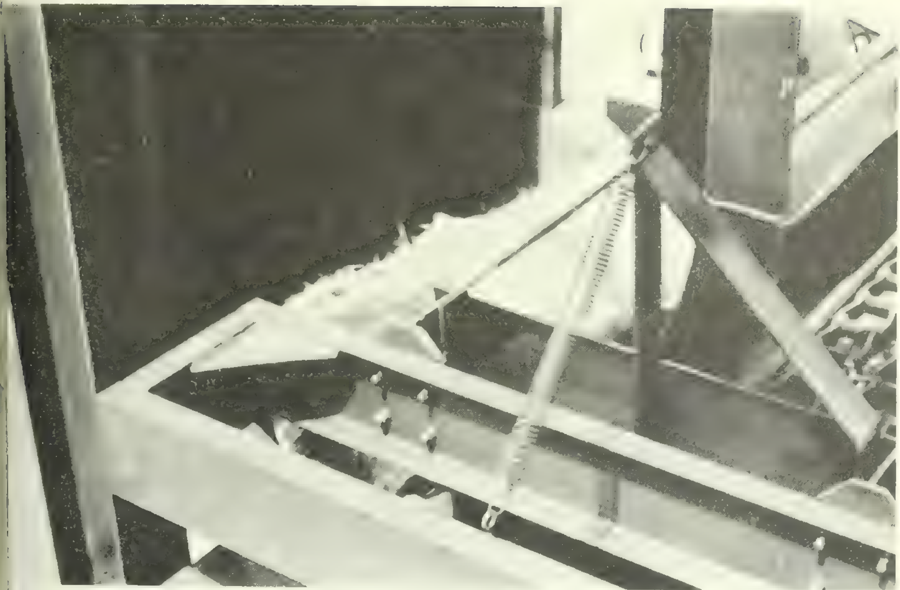


Figure 4.–Cutoff saw in operation.

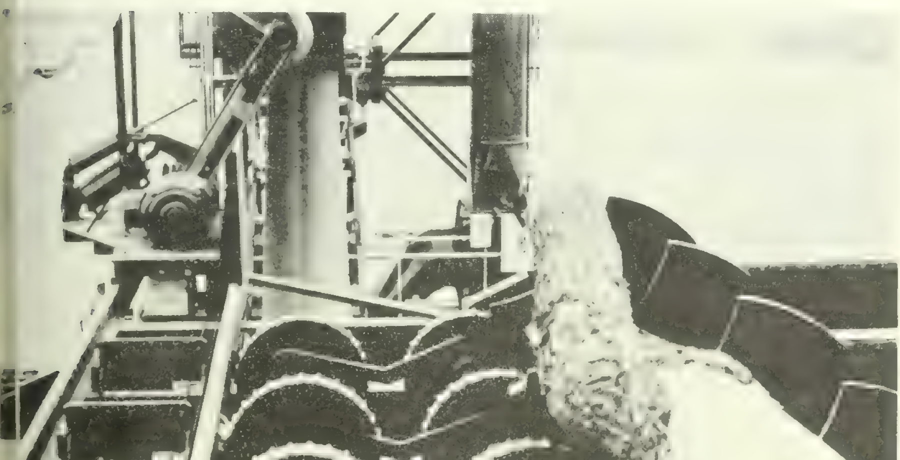


Figure 5.–Log being loaded onto debarker.

3. LM Model No. 200 HSA chain-saw cutoff, complete with control panel an motor starter (fig. 6).
4. 8- by 8-foot chip screen manufactured by Precision.
5. Two van truck loaders with feeder manufactured by Phelps.
6. Bark and waste hog manufactured by Bush Manufacturing Company.
7. Large-capacity storage bin manufactured by Carothers Brothers.
8. Miscellaneous log decks with stops, conveyors, log jack, log clam, etc., manu factured by Mellott.
9. Miscellaneous conveyors, transporters, supports, and walkways manufactured b Minneapolis Sheet Metal Works.

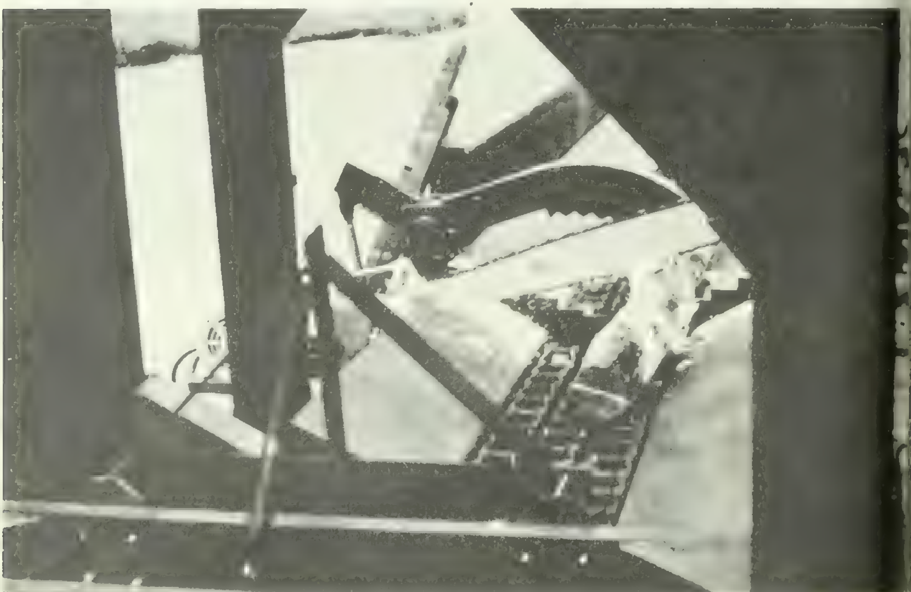


Figure 6.—Debarked log entering chipper.

The total cost for construction, $460,000, was shared by the Minneapolis Par and Recreation Board ($115,000 or 25 percent), the City of St. Paul ($115,000 25 percent) and the State of Minnesota, Department of Agriculture ($230,000 or 50 percent matching grant). The program was set up under a joint-powers agreemen between Minneapolis and St. Paul, with the latter being designated as the lead agency Bids to furnish the equipment, prepare the land, and install all components wer requested, and an award was made to the lowest bidder, Minneapolis Sheet Metal C

Construction was begun during January 1977, and the plant was ready for a tria run during August 1977. After the usual equipment shakedown problems, the plan was ready for operation.

A decision had previously been made that actual operation of the facility woul be best handled by the hiring of a private operator chosen by the open-bid metho

Northland Pulp Company was chosen as the operator. Production began, and things seemed to be going well. Chips and hog fuel were being produced and marketed.

1977–DISASTER!

The 1977 season opened with a bang. Suddenly trees were wilting in both cities in unbelievable numbers. In Minneapolis we had lined up 19 private contractors and felt comfortable. It turned out that they were not sufficient; even bringing in an additional 13 through an emergency bid did not give us enough. Fortunately, when we had asked for bids we requested two price quotations, one for free dumping at the chipper plant and a second price if the contractor had to find his own disposal area and pay his own dumping fee.

To help alleviate overload problems at the plant, all contractors working in Minneapolis were required to find their own dumping areas. The Hennepin County Public Works Department set up a burning site open to these contractors, and the bulk of the trees removed from Minneapolis and surrounding areas literally "went up in smoke." Our own city crews were aided in disposing of all material up to 22 inches in diameter by our renting four 22-inch Morbark chippers, which chipped trees right at the removal location on the street. This left for the large chipper only logs over 22 inches in diameter, which were cut properly for running directly through the chipper plant.

Unfortunately, things did not go as well for St. Paul. The contractors in St. Paul, as well as the city crews, had to haul all of the logs, brush, and other debris to the chipper plant. The removal of some 40,000 trees over a 4-month period caused brush and log piles to rise like mountains. It was estimated that by the end of summer some 30,000 trees were piled on the site.

The plant, of course, could not handle these volumes. Trucks found themselves having to wait up to 3 hours just to get through the gates. Then, because of mud, most of them had to be pulled into and out of the dumping areas by tractors. St. Paul hired cranes to unload trucks, and debris was piled 20 to 25 feet high. Attempts to pull logs out of the piles were extremely difficult because of all the entangled brushy material.

The chipper itself was running at full capacity for 1½ shifts per day, and the other shift was spent trying to keep it in repair. A lot of logs were being processed, but the volumes of brush (for which the plant had not been intended) were becoming huge. St. Paul then located and purchased two large log-chippers, one a Morbark and the other a Nicholson. They helped on the brush, but by the end of fall, tremendous volumes still remained. The standard joke of the day was, "Anybody got a match?"

Actual burning was considered. The air-pollution problem that would occur, however, would not allow for it. Since the ground upon which the trees were lying was an old landfill with undecomposed material many feet deep, it was feared that if this material were to catch fire it might not be easily extinguished. There was also the fear that methane pockets might exist in sizes sufficient to cause serious explosions.

By midwinter some progress had been made in reducing the volume, but it was still a substantial problem. Speculation then began about how much of a threat this pile of beetle-infested wood would become to elms in the surrounding area. There were two schools of thought. One held that the beetles would go no farther than a nearby

river bottom full of elms for them to feed upon. The second held that the winds a ciated with wide river valleys would blow them out into the neighboring areas cause serious tree losses.

We never found out who was right. It seems a welder making repairs on a piec machinery allowed sparks to ignite oil-soaked rags, which then ignited a gaso storage can in an old shack. The shack, in turn, caught fire, culminating in the acre wood catching fire. They burned out of control for 10 days. The fire department cc do little more than keep the chipper plant from burning up. The firemen were h pered by low pressure in the scarcely available fire hydrants.

The fire was finally brought under control, and the remainder of the debris allowed to continue to burn for an additional 20 days under controlled conditions.

1978–OPERATING!

The 1978 season was much better. The only brush allowed to be brought into area was carefully kept separated from the logs, and only what could be dispose in 1 day was allowed on site. Stockpiles of logs were held to reasonable sizes and s rated by fire lanes. The season ran quite well, and by the end of the year most mate had been processed.

During the summer of 1978 the plan produced for sale some $350,000 wortl chips. Prices received for the chips varied with their type, quality, and intended Total-tree chips (those not screened and with higher bark content) sold for $5 to per ton. The price varied, with debarked and screened chips selling for $9 per ton.

There were many companies buying chips; e.g., Horner Waldorf Paper Comp (located right in St. Paul), Certain-Teed Corporation (producers of building mate and also located in the suburban area), Celotex Corporation (in Iowa and Illin and both Owens-Illinois and Weyerhaueser Corporations in Wisconsin. A great m chips were sold for landscaping and agricultural purposes. Driving into the metro itan area, one sees tons of chips used as mulch in shrub plantings along highways.

It appears that some marketing problems will always occur. Value of chips va with the type and quality being produced. Most buyers need to have certain guaran with regard to volume, steady and even production flow, and long-term commitme Since our production depends on factors beyond our control (rate of disease incide weather effects on the disease vector, possibilities of improved disease-control meth or even cures), commitments of these types cannot be made. The primary proble that we are not trying to produce a salable product. We are simply trying to find a of disposing of a waste in a manner most efficient and economical for the taxpa

We are currently investigating two possible outlets for our chipped material. is with the local electric power company, Northern States Power, who could, a certain plant conversions, use all of the material we can produce. Since they have la storage capacity, they can even handle our extreme fluctuations in material flow. chips would be fed into their boilers along with coal in producing electricity.

The second possibility is to sell our chips to Guaranteed Fuels, which has rece (in cooperation with the Minnesota Department of Natural Resources) complete plant for waste wood (in the form of chips) to be compressed into pellets to be u

fuel. Their findings are that the pellets have a BTU content comparable to western l. A second finding, perhaps of more interest to Easterners, is that, although the U content of the pellets is not as high as eastern coal, they have the ability to nteract the sulfur problems inherent in eastern coal, to the extent that scrubbers not needed in many furnaces.

CONCLUSION

In summary, then, there are certain concerns that must be addressed when trying find a means of disposing of municipal tree debris:

1. First, it must be completely understood that our tree debris is debris, not a duct.

2. It is something that can be terribly expensive to dispose of; our concern should ply be to find the most economical method of disposal. If, along with this, a cer- profit can be derived, all the better. But profit should not be the prime motive.

3. Even though we are trying to do the most economical thing, we must also be cerned with the side effects of our disposal. In most instances, open burning is bably the least expensive method; however, it can also cause serious pollution blems, especially in large metropolitan areas. Landfilling, especially where the land- is owned and operated by the municipality itself, can look very attractive; however, need to consider what the future potential of the land could be if it were not ed by the burying of logs and brush, and how much the long-term capacity of this fill is being shortened by wasting it with this debris.

4. Finally, it must be remembered that the wood from municipal trees is just as able a natural resource as is the wood from forest trees. As with any natural urce, we have a responsibility to use it wisely. That wise use can vary from putting to our homes and structures in the form of lumber, roofing and insulation mate- ; to turning it into paper and boxboard; to burning it in furnaces, which saves r natural resources for future use.

MULCH FROM LIMB AND TRUNK DEBRIS

Dave Walker[1]

Abstract.–Faced with the rising cost of pine straw, Georgia Institute of Technology experimented with using site-generated wood chips for mulch. It was learned that, compared with pine straw, wood chips were less expensive, longer lasting, less flammable, and better at retaining soil moisture.

From 1970 to 1978, I worked on a research project at Georgia Tech called Lia ities to Assets. One of the major successes in this program was known as "orga mulching with wood chips." It was always interesting to see the expression on peop faces when they learned that during the years 1976 and 1977 we were given 10,(and 9,000 cubic yards of chip material at no cost to the Institute. That we were gi the material was hard enough to believe; however, that the material was processed a hauled to us for free was even harder to believe in a time when costs are constan rising on materials, labor, and equipment.

First, we had to see our own need. That came in 1970, when funds were hard come by for landscaping around our buildings. We thought pine straw was expens then, but look at it now!

Second, we had to find an alternative to the straw. Many times we fail to recogn a good idea simply because we are unable to picture something for what it co become instead of what it is. In this case, an ice storm during the winter of 1970 cau us to generate about eight truckloads of chip material when we had to bring in a p vate tree contractor to clean up the downed limbs Rather than throw this mate away, we tried using it around one of our buildings as a temporary mulch and found i the long run that it was far superior to the pine straw we had been using (fig. 1).

Third, we had to find a source of supply large enough to meet our demand. found that the tree companies were more than happy to give us the chips if they ha place to dispose of them at no charge. This is important as an incentive because m landfills charge a dump fee by the load, yard, or estimated tonnage, which in tu raises the tree contractors' overhead. Another way to look at it would be to s that a contractor's profit margins increase if his prices stay competitive with otl firms and yet his trucks are able to dump their loads at no charge. Keep in mind, ho ever, that the dumping site must be closer to the job site than the landfill, or the abc principle may not apply. In any case, at Georgia Tech, we had crews hauling to when they were within a 3- to 5-mile radius of our facility; most landfills were 7 30 miles away.

Fourth, we had a responsibility to the contractors. If they were going to proce haul, and give us the chip material, the arrangement had to be beneficial to them. C chip-recycle station was located on an abandoned street. The paved area meant th the trucks could come and go in any type of weather without fear of getting stuck

[1]Urban Forestry Consultant, Hayesville, North Carolina.

Figure 1.–Wood chips provide an attractive mulch around buildings.

emud or having flat tires, which would certainly be hazards at a local landfill. Be- e we were given the chips free and did not charge for dumping, the contractors ıld dump at their convenience. Most of the time the trucks would arrive before or t our normal workday when traffic on the campus was light (fig. 2).

What about the type of material and volume storage? In our research we found a separating the hardwood and softwood chips was an extra problem for the con- a or and required a lot of space. Most crews are chipping up whatever they come to d do not work on just one type of wood. The combined chip material worked very t actorily as an organic growing medium, as well as being attractive. The rougher, rigier chips were used to hold steeper slopes (up to 60 percent grades), and the n chips were top-dressed over this or used in areas of lesser grade.

As for volume storage, our facility had a total capacity of 10,000 cubic yards. o ever, because we were constantly drawing on our stockpile, we never reached p ity. Unlike leaves, the wood chips are generated year round, which means that ply is more constant than seasonal, thus eliminating overloads and handling ro lems.

What were some of the advantages in using the chips?

1. *Long lasting.*–The chips would last up to 3 years when applied in layers 4 to 6 c s thick.

2. *Fire safety.* Our research showed the chips to be far superior to pine straw or a s because of the larger particle size and moisture-retaining value.

Figure 2.—Ample dumping site with ready access for contractors.

3. *Moisture control.* We found that the wood chips would control water r on all grades up to 60 percent, slowing it down to allow for greater soil penetra (This does not mean that the chips will not float or wash. Any material will given enough force behind it; however, under normal slope conditions where a v head is not involved [no drainage ditches, or concentrated parking lot, or stree off], the chips can effectively control erosion.) Once the soil has absorbed the v the chips will drain to soil capacity. After this has occurred, the chip layer will act as a moisture blanket, increasing the amount of moisture available to plants during droughts. This fact is important in controlling watering and its labor co well as being beneficial for plant growth. No summer slump!

4. *Soil amendment.* The chips can be used in place of peat moss or othe incorporants if fertilizer is added.

5. *Mulching.* Chips make a fine mulch. The chips will weather to a un color within 6 months and do not require fertilizer if used strictly as a mulch. 1 year, this material can be worked into the ground, again without the nee fertilizer.

6. *Fertility.* We did not make any laboratory studies to determine the fe value of the chips; however, the observation of plant growth response withou fertilizer being added on mulched plantings would indicate a moderate suppl released over a period of time. We observed five varieties of hardwoods du study made in 1978, and the results showed a growth response of 3 to 4 feet d

e first year of planting. (I might add that this was a very dry year in Atlanta, and no ditional water was added except for two good waterings within 2 weeks after plant- g in late March.) The trees were 18- to 24-inch year-old seedlings.

What about value? At first, we put a $1 per-cubic-yard figure on the chips just to ve us a means of tabulating some type of value system. However, when the chips are mpared with other materials, a much higher value can be realized.

Material	Estimated cost (1978)
Peat moss	$30/yard
Perlite	$20/yard
Sawdust	$5/yard
Vermiculite	$20/yard

Given the above figures, it would not be unreasonable to put the value of the od chips at $10 per cubic yard. In the beginning, I said that we received 10,000 and 000 cubic yards of chips during 1976 and 1977. If the chips are valued at $10 per rd, we received approximately $100,000 per year free.

The chip idea is not a Utopia, and it takes a lot of hard work to get the program rted. A successful program must have a good location convenient to both supply d demand, an all-weather site, equipment to work it, and personnel who can sell the ea to local tree contractors as well as local landscapers. But the system does work.

PRODUCTS FROM MUNICIPAL TREES

Edward A. Lempicki[1]

Abstract.—Shade trees along city streets and state highways and those near suburban homes often reach a large size and have butt logs suitable for many specialty products. However, when these trees are felled, they are all too often used only for fuelwood or wood chips, or hauled to landfills. The following is an example of one company's experience in turning this underutilized material into an interesting and profitable commodity.

Sam Willard started Shearer Tree Service Company in 1949. Employing appro mately 40 people, his company is involved in normal arboreal services such as pruni planting, spraying, removal, and maintenance. In 1974, Sam was paying about $20,0 per year in landfill fees to dispose of tree removals. Because of the noncompactab bulky nature of this material, the landfill rates were expected to increase steadily, th making this form of disposal economically unattractive.

Sam decided to do something about the problem and began his effort with t purchase of a used Frick Sawmill, along with an edger, crosscut saw, planer, sta pointer, and metal detector (fig. 1). Instead of hauling his tree removal material

Figure 1. Urban tree removal material is processed through a sawmill and Alaskan Mill sawi systems.

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fills, he began processing the saw logs through his mill and converting the tops to wood. Lumber, timbers, nursery and survey stakes were the original products from mill. The logs are first scanned with a metal detector before any processing is mpted. Metal in the form of nails, spikes, or barbed wire is a common component ogs acquired in tree service work. Once located by the metal detector, the metals t be removed. This removal can be a time-consuming process; however, this partic- mill does not concern itself with high production, so the extra time taken to ove metal from some logs is well spent. Logs are processed on a lumber order basis only high-grade lumber (FAS and SEL) is kept in inventory. His suburban location ved a good spot for marketing specialty products to homeowners in the area.

The mill has evolved since its first days of operation and provides a wider range of ducts, including free-form furniture, clocks, planters, and decorative plaques. This of product is made possible with the use of an "Alaskan Mill" sawing system. This ialized machinery basically consists of a metal frame with guide rollers, two chain power drives, and a large ripping chain. Suitable logs are elevated at one end and onally cut with the rip chain, which results in thick, matched slabs. These slabs are as raw material for the free-form furniture styles: tables of all kinds and sizes, bar counter tops, plaques, clocks, and many other highly decorative items. Variations pecies, grain pattern, color, and figure greatly enhance the free-form product's ketability. This type of sawing accentuates the wood grain in such a way that the ern normally produced is quite unlike that shown in standard sawn lumber. Large ps and abnormal tree butts are also sawn in this fashion, creating unique and rative patterns.

The diagonally cut slabs are stickered and air-dried for 3 months before kiln ng. The operator uses a small West Air Kiln system for drying these thick slabs. schedules are a very important facet of the operation since the product must be of checks or splits if it is to bring its maximum price. Normal kiln schedules had e adapted to fit this particular type of material. After kiln drying, the slabs are ed and sold as is, or are processed into a finished free-form furniture item.

Willard's sawmill is a classic example of how urban tree removal material can be essed and marketed. His products are a response to the specific type of raw mate- handled. The utilization of these municipal trees is almost complete; logs are essed either through the sawmill or Alaskan Mill, large topwood is marketed as ood, branches are chipped at the point of origin and sold as mulch, and the saw- from the mill is sold to local horse owners for use as bedding. This unique urban ill is one answer to the problem of municipal shade tree utilization.

FIREWOOD FROM MUNICIPAL TREES

Jay W. Lowery[1]

Abstract.—Firewood is becoming a necessary item in the life of Americans as we face increasing energy shortages. This paper summarizes an effort to supply the citizens of Atlanta with an energy source obtained from wood residues produced from the city's forestry operation.

We all know that America is the land of plenty; as a consequence this great co has waste wood byproducts in many forms. It is estimated that in the city of At 67 to 85 percent of materials going into the landfills is wood in the form of p cardboard, and wood scraps. Materials are being buried that could be used for he or recycled for products.

The supply of firewood has reached critical levels in less fortunate countrie average of one-fourth the annual income for an average family in Upper Volta is for firewood. In China, the reforestation program is being severely hindered b theft of newly planted trees, which are being used for firewood.[2]

Deforestation, in the name of firewood, has been occurring at alarming ra Africa, Asia, and Latin America. As a result, severe land problems are develo Erosion and floods are becoming rampant, and deserts are expanding because of unstable soil surface created by the loss of trees. Some areas which have depleted firewood sources have resorted to burning animal dung, thereby breaking the de balance of the nutrient cycle in crucial areas.

Will this country have to meet a critical period before the value of firewoo be fully realized? Let us look once more to the less fortunate countries: (1) they expended, for the most part, all firewood materials; (2) they are not prosperous e to switch to an oil product; (3) they have no way to stay warm or cook their Result? CRISIS. Solution: A sonic device has been developed that breaks down and other organic materials into methane gas and a byproduct that is good con Here a crisis was needed before a solution to a known problem could be foun cost of the project presents a problem; however, it does have potential.

These are extreme cases; however, they are pertinent to the problem at ha our cities we are experiencing similar problems: (1) a high concentration of p (2) oil, gas, and electricity are becoming scarce and expensive; (3) the growth of has stifled, if not totally eradicated, the supply of firewood.

Firewood consumption dropped sharply for the first 5 decades of this ce with the onset of oil, gas, coal, and electricity used in cooking and heating. In years, however, firewood has become a sought-after item in today's market

[1] Parks Arboriculture Manager, City of Atlanta Bureau of Parks and Recreation, 260 C Avenue, SW, Atlanta, Georgia.

[2] Eckholm, E. P. 1975. The other energy crisis: FIREWOOD. Am. For. 81(11):12–13.

jor part of the market exists in communities in and around the Nation's cities. A jority of the homes being built in the East include wood-burning fireplaces and/or ves.

Although this trend may be limited by increased air pollution standards, people ntinue to search for alternatives to their dependency on oil.

Ironically, there is now cash for both "culled" or "worthless" trees and residues t by timber or pulpwood operations. This market is either for firewood or chip terial.

In Atlanta, Georgia, the wood residues taken from the 3,000 acres of parks and 00 miles of rights-of-way were being buried in the landfills. Within the last few rs, two programs have developed: the increased use of wood chips and the free wood program, which has brought tremendous public response and at the same e saved the city money. It also has reduced pressure on the landfill operations und the city.

Since 1975, two of Atlanta's three municipal landfills were closed, placing a hard- b on all dumping activities. The one remaining site was located at an inconvenient a outside the perimeter. Average travel time to and from the area averaged 3½ hours day. By having three crews to handle logs and chip materials, a total of approxi- tely 10½ hours (depending on weather and traffic conditions) is spent transporting s to the landfill area.

A proposal was made to establish three holding areas in Atlanta: one on the north e, one around midtown, and one on the south side of town. Small areas of parkland ich were not being used and were not close to residents were designated as dumps the tree residues.

Before this system could be implemented, the Mayor and City Council had to give r consent. The city cannot give to a nonprofit organization or dispose of "city perty" without holding a public auction or obtaining the consent of the Mayor and ncil. By identifying the residents of Atlanta as the "nonprofit organization" and ving that the program would save the city money, the proposal was approved.

Costs for using the landfills were as follows:

- –average 21 manhours (2 men/truck) at an average of \$4.50/hr. = \$94.25 per day.
- –average 10½ running hours at an average equipment cost of \$3/hr. = \$31.50 per day. Total: \$125.75 per day.
- –\$125.75 X 5 (days/week) = \$628.75 per week.
- –\$628.75 X 50 (work weeks/year) = \$31,437.50 per year.

With the implementation of the program, it was estimated that travel time would educed by 50 percent, a savings of \$15,718.75 per year. In actuality, there is only vings of \$10,397.

Now that the political red tape has been cut, the Law Department blessed the gram. Questions were raised about the liability of people cutting wood on city perty. It was decided that warning signs would be erected. Although this action ld not totally relieve the city of its liability, it did give fair warning to users f. 1).

Figure 1.–Signs were erected to provide warning and use information to the public.

Although there is no one assigned to oversee these woodyards, the implications of the signs keep the people honest. The reason for the limitations on trucks is to disco age commercial people from taking advantage of this wood source.

In lieu of having a person stationed at each site, all crews in the Bureau of Pa and Recreation have been asked to report any discrepancies they observe, either wh working nearby or just passing the areas. To date, only a few incidents have occurr

On the few occasions that residents or commercial people have tried to use th areas for dumping, there have been no problems in having them clean up the area prosecuting them according to the dumping laws of the city.

The question of selling this wood was considered; however, this operation i temporary measure, and the massive amount of paperwork, amending of ordinanc and setting up new systems make this impractical.

Firewood has become a backup heating and cooking source during times of storms, floods, and blackouts (fig. 2). The city is working in cooperation with C Defense to supply firewood to victims of any major catastrophe.

Because of Atlanta's climate and rainfall, wood cut and stored in the open last only 3 to 4 months. Each year the city culls decomposing wood and chips other uses.

ure 2.–Ice storms produce problems of repair and removal for Atlanta residents, but also increase demand for firewood due to power outages.

Chips are the most versatile and economical use of wood accumulated in Atlanta's sy:em. Chips are being used in place of asphalt, concrete, sand, rock, and dust. Using ips in place of these materials saves replacement cost, restores nutrients to the regu-a nutrient cycle, and disposes of a material which was once taking up landfill space.

The encouraging part about wood chips is that after only a few hours of educating th city administration about the benefits of this byproduct, demand for wood chips son exceeded supply. Presently, requests average 80 truckloads (40,320 cubic feet) pe week. With the existing resources, the program is able to supply only 10 truck-oads (5,040 cubic feet) per week, with 20 loads (22,400 cubic feet) of wood going to th woodyards. With the purchase of a whole-log chipper, the program will not be able tc neet the current need, but we will be using *all* wood waste products.

Future efforts are being directed toward using waste materials from tree busi-nesses, utility companies, and, possibly, construction companies in an effort to increase th supply of chips in the system.

Chips, as mentioned before, are replacing traditional ground covers in he park sy em. However, all trees, shrubs, and flower boxes do not have a mowing edge of m ch around them, nor have all the banks of the park system been erosion stabilized.

The only problem in using chips was presented during an arts festival where they we being used as a ground cover in a tent. The Fire Marshall refused to approve "flam mable material" being used in an "enclosed" area, even though the chips' wate retaining ability was higher than the first 3 inches of soil.

If you have a valuable resource such as firewood or chips, get excited about i you are sitting on a gold mine. You may not be able to prove savings in actual budg dollars, but improving an operation, developing a complete environment, and solvin maintenance problems are measures which cannot be budgeted for, but they do sav dollars.

FUEL PREPARATION FOR WASTE WOOD BOILERS

Alex D. Cobb, Jr.[1]

Abstract.—After proper preparation, wood residue may be used as fuel or as raw material for such products as horticultural mulch, animal bedding, poultry litter, particleboard, fireplace logs, and fuel pellets. The reuse of waste wood requires an understanding of waste wood boilers, wood-reduction machines (hogs), waste loads, economic considerations, and the services provided by consultants.

INTRODUCTION

Annually the volume of solid waste in the United States amounts to over 4 billion s and is increasing at a disturbing rate. Everyone -producers and consumers - tes solid waste. The larger and more affluent the population, the greater the vol- of solid waste. The problem is compounded by archaic municipal and county ection and disposal practices.

Of the solid waste produced annually in the United States, animal waste accounts some 2 billion tons; mineral waste for more than 1 billion tons; agricultural waste nearly 650 million tons; household, commercial, and other municipal waste for ut 300 million tons; and industrial waste for almost 130 million tons. Projections that solid waste generated in the metropolitan areas will more than triple by the 2000.

Sixty-five percent of our population now lives in urban areas. Generally, cities e for the least expensive means of solid waste disposal open dumping and open ing. These methods pollute the air and water, devour valuable land, pose fire rds, breed germs and—worst of all—waste natural resources. Over the last 5 or 10 s, air and water pollution problems have caught the interest of the public. Only ntly has attention been given to solid pollutants and the need to conserve valuable erials that would otherwise be lost in countless city and town trash heaps.

There is uncertainty about how much municipal waste goes where, but the Federal ernment has estimated that 77 percent goes to open dumps, 10 percent to inciner- tes, and 13 percent to sanitary landfills. The remaining waste is converted into com- or salvaged for reuse. Studies have shown that waste wood constitutes 10 to 20 ent of landfill material and takes a disproportionate share of landfill space because oes not compact as well as other materials. Furthermore, as buried wood begins to mpose it forms methane, which is a colorless and odorless but highly inflammable ocarbon gas, sometimes known as marsh gas. Gasification of the rotting wood es pockets which later collapse in the landfill.

What is the solution? The open dump is not the solution. Sanitary landfills are a stopgap measure. Incineration is becoming increasingly costly and is subject to gent EPA regulation. More importantly, none of these methods recovers resources;

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they merely dispose of them. The method of the future, therefore, is to reclaim muc of our urban refuse and reuse it.

WASTE AS FUEL

Many industrial plants are spending considerable amounts of money to get rid waste materials that are a potentially valuable supplemental energy source. One stuc indicates that combustible waste equivalent to over 700,000 barrels of fuel oil is throw away daily in this country.

Plenty of waste is available, the equipment to process and burn it is on the marke and the economics are favorable. In addition, burning waste as a supplemental energ source reduces fossil-fuel requirements. For example:

- Less than 1½ tons of general plant waste produces heat equivalent to that pro duced by 1 ton of coal.
- One ton of this waste produces heat equivalent to that produced by over 60 gal lons of fuel oil.
- Less than 1 ton of this waste produces heat equivalent to that produced b 8,000 cubic feet of natural gas.

Any plant requiring 1,000 pounds of steam per hour and generating 1 ton of wast per day should consider using waste-fuel firing as a supplementary source of energ Three factors should be considered when the potential of waste as a fuel source being evaluated: the amount of onsite waste produced; the BTU content of this wast and an economic comparison of the waste wood fuel and the fuel presently in use.

The following chart shows the heating values of some common waste woo materials:

HEATING VALUE OF COMMON WASTE MATERIALS

Waste material	Heating value/lb (as fired) (BTU)[1]
Used automobile tire casings	13,000
Type "O" trash (paper, cardboard, wood, boxes, sweepings	8,500
Wood sawdust (pine)	9,600
Wood sawdust	7,800-8,500
Wood bark (fir)	9,500
Wood bark	8,000-9,000
Oak scrap	7,990
Pine scrap	8,420

[1]BTU = British Thermal Unit the amount of heat required to raise the temperature of 1 lb. of water 1° F at or near 39.2° F.

Many industries with high energy requirements are switching from fossil fuels t wood. Wood-energy production could play a very important role, especially in suc highly timbered areas as the South and West.

RECOVERING THE COST OF CONVERSION

Industry experts have estimated that the cost of converting to a waste wood boiler can usually be recovered, from savings, within 3 to 5 years, depending on the location of the plant, the type and amount of onsite waste generated, and the cost of other fuels.

A major factor to be considered is the rather high initial capital cost to purchase and install the fuel-handling, processing, and firing equipment required with a waste wood burner. However, this is more than offset by wood fuel that will be used at a cost vastly lower than that of commercial-grade fuel oil or natural gas.

In one system, which is about 3 years old and uses the fluid-bed combustion chamber, the total first-year investment in boiler-house equipment and a 20,000 cubic-foot material-handling system came to $240,000. However, the first year's fuel savings (using wood residue instead of 1 million gallons of No. 6 fuel oil at $0.30/gal) amounted to $285,000. Subtracting $7,770 per year for increased maintenance costs, electricity, and insurance resulted in a net savings of $277,230. So, in the first year the owner saved enough to pay for the system, plus a small profit. In succeeding years, he will be putting at least $277,230 annually toward profits.

TYPES OF WASTE WOOD BOILERS

Numerous conventional boiler systems are now being designed and installed to provide industry with heat, process steam, and onsite electricity from raw-wood material as a fuel. These systems are primarily of three basic types:

Dutch oven.– The oldest and most simple boiler system–though not necessarily the most efficient or the most pollution free–is the Dutch oven. This is a large refractory-lined compartment, with grates, which sits in front of and below a boiler. A large pile of fuel–in our example, shredded or hogged wood scrap–is maintained in the oven, where primary breakdown takes place. Combustion is completed in the chamber situated behind the radiant section of the boiler. The Dutch oven has been known to perform satisfactorily even with very wet fuel, but it does not respond well to widely fluctuating steam demands, as the large pile takes considerable time to burn down or build up, and the system must be attended constantly. Nevertheless, if fired conservatively with a reasonable fuel (not overfired), Dutch ovens can meet most anti-pollution requirements.

Stoker feeder.–A second, very popular way to fire wood in a boiler is through a stoker feeder or spreader-stoker. Here the incoming fuel is metered into a wide, flat, horizontal air stream and spread in a thin bed over grates for aeration and uniform exposure to combustion. Fuel feed is more easily controlled to follow fluctuations in steam demand. If the grates are at the bottom of a rather large refractory-lined combustion chamber, performance can be quite satisfactory. However, it should be pointed out that stoker-fed systems, in general, require cinder reinjection and high-efficiency collection equipment to meet today's rigid air pollution standards.

Suspension burners.– A third boiler system burns the fuel in suspension; these are of two types: (1) A cyclonic burner, which usually requires dry fuel with moisture content of 15 percent or less, as might be found in dry planer-mill shavings, sawdust, or kiln-dried wood scrap. The material must be finely pulverized for feeding the

they merely dispose of them. The method of the future, therefore, is to reclaim mu of our urban refuse and reuse it.

WASTE AS FUEL

Many industrial plants are spending considerable amounts of money to get rid waste materials that are a potentially valuable supplemental energy source. One stu indicates that combustible waste equivalent to over 700,000 barrels of fuel oil is thro away daily in this country.

Plenty of waste is available, the equipment to process and burn it is on the mark and the economics are favorable. In addition, burning waste as a supplemental ene source reduces fossil-fuel requirements. For example:

- Less than 1½ tons of general plant waste produces heat equivalent to that p duced by 1 ton of coal.
- One ton of this waste produces heat equivalent to that produced by over 60 lons of fuel oil.
- Less than 1 ton of this waste produces heat equivalent to that produced 8,000 cubic feet of natural gas.

Any plant requiring 1,000 pounds of steam per hour and generating 1 ton of wa per day should consider using waste-fuel firing as a supplementary source of ener Three factors should be considered when the potential of waste as a fuel sourc being evaluated: the amount of onsite waste produced; the BTU content of this wa and an economic comparison of the waste wood fuel and the fuel presently in use.

The following chart shows the heating values of some common waste wo materials:

HEATING VALUE OF COMMON WASTE MATERIALS

Waste material	Heating value/lb (as fired) (BTU)[1]
Used automobile tire casings	13,000
Type "O" trash (paper, cardboard, wood, boxes, sweepings	8,500
Wood sawdust (pine)	9,600
Wood sawdust	7,800-8,500
Wood bark (fir)	9,500
Wood bark	8,000-9,000
Oak scrap	7,990
Pine scrap	8,420

[1] BTU British Thermal Unit the amount of heat required to raise the temperature of 1 lb. of water 1° F at or near 39.2° F.

Many industries with high energy requirements are switching from fossil fuel wood. Wood-energy production could play a very important role, especially in s highly timbered areas as the South and West.

RECOVERING THE COST OF CONVERSION

Industry experts have estimated that the cost of converting to a waste wood boiler can usually be recovered, from savings, within 3 to 5 years, depending on the location of the plant, the type and amount of onsite waste generated, and the cost of other fuels.

A major factor to be considered is the rather high initial capital cost to purchase and install the fuel-handling, processing, and firing equipment required with a waste wood burner. However, this is more than offset by wood fuel that will be used at a cost vastly lower than that of commercial-grade fuel oil or natural gas.

In one system, which is about 3 years old and uses the fluid-bed combustion chamber, the total first-year investment in boiler-house equipment and a 20,000 cubic-foot material-handling system came to $240,000. However, the first year's fuel savings (using wood residue instead of 1 million gallons of No. 6 fuel oil at $0.30/gal) amounted to $285,000. Subtracting $7,770 per year for increased maintenance costs, electricity, and insurance resulted in a net savings of $277,230. So, in the first year the owner saved enough to pay for the system, plus a small profit. In succeeding years, he will be putting at least $277,230 annually toward profits.

TYPES OF WASTE WOOD BOILERS

Numerous conventional boiler systems are now being designed and installed to provide industry with heat, process steam, and onsite electricity from raw-wood material as a fuel. These systems are primarily of three basic types:

Dutch oven.—The oldest and most simple boiler system—though not necessarily the most efficient or the most pollution free—is the Dutch oven. This is a large refractory-lined compartment, with grates, which sits in front of and below a boiler. A large pile of fuel—in our example, shredded or hogged wood scrap—is maintained in the oven, where primary breakdown takes place. Combustion is completed in the chamber situated behind the radiant section of the boiler. The Dutch oven has been known to perform satisfactorily even with very wet fuel, but it does not respond well to widely fluctuating steam demands, as the large pile takes considerable time to burn down or build up, and the system must be attended constantly. Nevertheless, if fired conservatively with a reasonable fuel (not overfired), Dutch ovens can meet most anti-pollution requirements.

Stoker feeder.—A second, very popular way to fire wood in a boiler is through a stoker feeder or spreader-stoker. Here the incoming fuel is metered into a wide, flat, horizontal air stream and spread in a thin bed over grates for aeration and uniform exposure to combustion. Fuel feed is more easily controlled to follow fluctuations in steam demand. If the grates are at the bottom of a rather large refractory-lined combustion chamber, performance can be quite satisfactory. However, it should be pointed out that stoker-fed systems, in general, require cinder reinjection and high-efficiency collection equipment to meet today's rigid air pollution standards.

Suspension burners. A third boiler system burns the fuel in suspension; these are of two types: (1) A cyclonic burner, which usually requires dry fuel with moisture content of 15 percent or less, as might be found in dry planer-mill shavings, sawdust, or kiln-dried wood scrap. The material must be finely pulverized for feeding the

burner. (2) A fluidized bed unit which burns either dry or wet fuel having up to 55 60 percent moisture content. The dryer wastes, of course, have a higher BTU conte For example, kiln-dried scrap wood contains approximately 16 million BTU's per t which is the equivalent of 114 gallons of fuel oil or 16,000 cubic feet of natural g

Waste wood boilers must, in most cases, be prepared to operate overnight and weekends. Thus, it will be necessary to have a storage system for the wood fuel, jus it is necessary to provide onsite storage for fuel oil or liquified gas. Storage bins usec connection with waste wood boilers are generally tall silos with either mechanical pneumatic infeed and discharge conveying systems for loading and unloading. ' wood fuel must be hogged (reduced in size) to facilitate storing and conveying. H ging is necessary even though some of the units will burn large chunks of wood; o ously, large chunks cannot be stored or conveyed well, so it is necessary to hog fuel down to a manageable size.

FUEL PREPARATION HOGS

Fuel preparation for waste wood boilers is accomplished by a machine calle hog–sometimes referred to as a hammermill, shredder, or pulverizer. The derivatior the term "hog" is not accurately known, but it may have something to do with voracious appetite these machines have for devouring waste materials–especially w waste from sawmills, lumber mills, plywood and veneer plants, wood-manufactu operations and, of course, urban wood waste. Hogs are used to grind bark large qu tities of it, in fact–which is removed from the raw logs in sawmills and pulpmills.

Some hogs employ a unique cutting action involving stationary anvils positio on the side of the machine with rotating teeth (hammers) that pass through rectar lar pockets formed by these anvils. This positive cutting action between the teeth the anvils performs what amounts to the first particle-sizing function in a two-st process.

The second sizing action occurs when the material cut by the action of the te against the anvils is directed downward and across a curved particle-sizing screen wl fits underneath the rotating element. The screen contains either round or rectangu shaped openings whose size is determined by the specific application for which machine is sold. Obviously, small, round or square holes are used to produce fine, s dust-like material; larger round or rectangular openings produce chunky pieces ha a greater cross-section and length.

Hogs can be furnished with either gravity infeed or horizontal infeed of material to be processed. However, horizontal infeed models, which are desig primarily for handling long, flat pieces of scrap over 8 feet long, have restrictions the thickness of material which may be processed, depending on the diameter of cutting circle. None of these horizontal-feed models would be suitable for cer types of waste, such as bark, small cutoff and blocks, loose sheets of paper, and sim materials.

Hogs made by Montgomery Industries, for example, are available in the follov series: HD, PM, PM-KC, CS-KC, XL-KC, and NAS. The difference in each series is diameter of the cutting circle of the teeth and/or whether the anvils are mountec the side of the hog in a stationary position (as is the case with HD and PM models),

mounted on a pivot shaft to swing away from the cutting area on severe impact with tramp steel (as with the KC and NAS models).

VARIETIES OF HOGS

The HD model has an 18¾-inch cutting circle, and the PM model has a 22-inch cutting circle. Both models employ 2-inch-wide cutting teeth and 2-inch-wide anvils mounted on the side of the housing. The anvils are adjustable to maintain the proper tooth-anvil clearance for efficient hogging. The wear surfaces of both teeth and anvils are hardfaced for extra long life, and when worn may be rebuilt at about half the cost of new parts. The hogs will handle light tramp steel ¼ inch and smaller, nails, small bolts, and steel strapping. An internal bronze shearpin arrangement protects against damage from heavy tramp steel.

The HD and PM models can be furnished with either gravity discharge or an integral fan for applications where it may be more convenient to pneumatically convey the material after grinding. The integral fan model uses less floor space than a gravity-type hog with a separate fan, as only a single motor and drive is required; two motors and two drives are required when the fan and hog are separate.

The HD and PM models are normally equipped with a steel flywheel which provides additional energy to carry the rotor through surge loads. Integral fan models normally require a V-belt drive because the shaft speed seldom coincides with the full-load motor speed. Bottom discharge models are normally connected directly to the motor with a flexible coupling because the first cost on the flexible coupling is lower than the cost of a V-belt drive.

The range of sizes on the HD and PM series, measured parallel to the shaft, starts with a small 10-inch model and increases in 8-inch increments to a 74-inch rotor length. Such hogs are generally used for most light and medium sawmill, lumbermill, and wood-furniture applications to process wood scrap, small quantities of bark, veneer roundup, broken pallets, and similar industrial waste.

Cutting circles on the KC and NAS hogs range from 22 to 54 inches. The teeth and anvils on these models are 3 inches wide and are hardfaced for extra long life. The anvil points are mounted on swinging anvil holders supported in a yoke and pivoted so they will swing away from the cutting circle if large tramp steel enters the hog. On such occasions, a trip latch releases and drops the screen, preventing serious damage; a pressure switch activates a signalling device which informs operating personnel that the protection mechanism requires resetting.

The KC models and the NAS hog are designed for gravity discharge only, with the exception of one model of the Montgomery Railroad Crosstie Destroyer, which accepts full-length ties horizontally. No flywheels are required with these models because of the large mass of the rotating element. Sizing on the KC models, measured parallel to the shaft, commences with 15 inches of rotor length and increases in 6-inch increments to 5 inches. The NAS model has been built as large as 87 inches of rotor length. Applications include grinding heavy bark (in sawmills and pulpmills), railroad crossties and boxcar dunnage, demolition waste, tree limbs, discarded tire casings, and soft metals.

SELECTING THE PROPER HOG

There are three major factors to be considered in selecting a hog for any appli tion: the size of the waste, including length, width, and thickness; the quantities waste, including average flow rates and maximum surge rates; and the desired size a use of the final product.

First, the bulk dimensions of the scrap must be known to ensure that the wa material will fit into the opening of the hog. When dealing with urban wood waste, t maximum width of the scrap is used to determine the minimum hog infeed openi parallel to the shaft. The maximum thickness of the scrap and the type of material used to determine the proper bearing size. The maximum length of the scrap is used determine the height of the upper infeed hopper, if a gravity-infeed model is select or whether the length of the material requires a horizontal-feed model.

Second, the capacity of the hog selected for a given application must be adequ to handle not only the average flow of incoming material, but also occasional su loads caused by a sudden buildup on the infeed conveyor.

Third, the required particle size governs the screen size, and this in turn ha substantial bearing on hog selection and capacity. The larger the screen openings, t larger the hog capacity for a given size. If the desired size of the end product and use are known, it is possible to select a screen opening that will produce the app priate product. The following chart shows the capacities of various hogs:

WOOD BLOCKS, EDGINGS, AND SLABS
Average capacity (lbs/hr)

Hog size HD series (inches)	Screen size			HP required	
	3"	1½"[1]	¾"[1]	Max.	Min.[2]
18	10,800	5,400	2,700	97	50
34	20,400	10,200	5,100	182	50
58	34,800	17,400	8,700	310	60

[1] The screen area on slabs must be 2 inches or larger to keep the screen from filling up chips and acting as a brake on the rotor.

[2] Minimum horsepowers shown are required to accelerate the hog up to speed (norm 1,200 RPM) within 30 seconds.

There are many other factors used in selecting the correct hog for a given ap cation. Among these are: size of infeed opening, bearing size, maximum bearing spe wood species, and drive selection.

SCREEN SIZES FOR WASTE WOOD BURNERS

For hogs used in the preparation of fuel for waste wood burners, there are th size ranges, depending upon the type of boiler in use. For coarse boiler fuel, a 3-i screen is recommended. For grinding waste wood to use as fuel in boilers with au matic stokers or fluid-bed burners, screens with 2-inch holes are recommended, as baffles welded transversely along the outer surface of the screen to prevent sticks fr

assing into the discharge conveying system, thus causing a blockage somewhere down he line. Cyclonic-type burners need a two-stage grind to produce the finely pulverized naterial required to support combustion: the primary breakdown unit uses a 1-inch creen; the secondary unit is a high-speed hammermill that reduces material to less han ¼ inch.

ESTIMATING WASTE LOADS

The prospective customer for a fuel-preparation hog would be expected to furnish ne average and surge flow rates of material going to the hog. These rates should be ncorporated into the quotation by the factory as part of the design conditions under vhich the performance of the hog is guaranteed. Consulting engineers or suppliers of vaste wood boiler systems will generally verify these figures with the hog manufacturer.

In the case of wood-processing industries, such as pulpmills, sawmills, veneer mills, imension mills, and other lumber manufacturers, certain waste factors are known rom experience and can be used as rules of thumb in estimating the amount of wood crap available for boiler fuel or other recyclable material. Following are some examples:

Pulpmill. -The bark from a standard cord of wood (128 cubic feet) will weigh 700 pounds at 50 percent moisture content. The quantity of oversize chips produced when chipping a cord of wood is approximately 5 percent.

Sawmill.—Determine plant production in log feet per hour. For estimating purposes, use 1,200 pounds of bark per 1,000 log feet. The amount of green sawdust produced when sawing logs to produce 1,000 board feet of lumber is approximately 2,000 pounds per 1,000 log feet.

Veneer mill.—Determine plant production in log feet per hour. The amount of veneer roundup and clippings is approximately 5,500 pounds per 1,000 log feet. The amount of cores produced, whether hogged or chipped, is approximately 2,450 pounds per 1,000 log feet.

Planer mill.—Multiply the plant production in board feet per hour by 5 percent to determine the waste load in board feet per hour. Then multiply this quantity by the weight per board foot to determine the waste load in pounds per hour. For estimating purposes, use 2½ pounds per board foot for pine; 3½ pounds per board foot for hardwood.

Dimension plant.—Multiply the plant production in board feet per hour by 45 percent to determine the waste load per hour in board feet per hour. Then multiply this quantity by the weight per board foot to arrive at the waste load in pounds per hour. For estimating, use the same weights for pine and hardwood listed above under Planer mill.

Furniture plants, industrial and urban wood wastes. Where the customer does not have accurate information on the expected waste loads, but the material is being accumulated (perhaps from a belt conveyor, in buggies, carts, bins, or haul-off

containers) determine the cubic content of the bin or container and reduce th
quantity by 50 percent to allow for voids which are created when material
tumbled loosely into the container. Multiply this approximate volume of sol
wood by the appropriate density factor in pounds per cubic foot to determine th
quantity of actual waste in pounds for each load. Knowing the average number
loads for each container on an hourly or daily basis would provide a fairly acc
rate basis for selecting the proper hog size. An alternative method where mater
is being conveyed on a belt would be to scrape off and weigh the material th
passed a certain point on the belt in 15 seconds, then multiply this weight by 2
to obtain the approximate pounds per hour to be processed by the hog.

CONCLUSION

Because all plants, as well as their energy requirements and applications, a
different, a plant considering conversion to waste wood fuel should commission
energy study by a qualified employee or outside consultants.

In addition to its use as fuel, waste wood has many other potential applicatio
Wood residues have the following uses: as animal bedding and litter to be sold to ridi
stables, kennels, stockyards, zoos, biological laboratories, and auction barns; as absor
ent materials to be sold to service stations, machine shops, butcher shops, and me
packers; as mulch to be sold to nurseries, landscapers, gardeners, and governme
agencies; and as industrial supply for making particleboard, fiberboard, hardboard, a
molded products.

MARKETING URBAN WOOD RESIDUES

John W. Howard[1]

Abstract.—This study defines the characteristics of wood residues that affect their marketability, discusses the processing required to upgrade residues to useful wood fiber, and lists potential markets and dollar values for various residues.

In this presentation, I will discuss the characteristics of wood residues that affect ieir marketability, the types of processing required, the potential markets, the proce- ures for marketing, and the monetary value involved.

The characteristics of wood residues that affect marketability and value are: pecies, moisture content, physical form, and degree of cleanliness. Wood residues iay be composed of hardwood species, softwood species, or a mixture of both. Green ood contains 40 to 50 percent moisture, air-dried wood 15 to 25 percent, and kiln- ried wood less than 10 percent. Wood residues may exist in the form of sawdust, iavings, chips, slabs, boards, blocks, trunks, limbs, leaves, or twigs. Wood residues iay be clean, or they may be contaminated with dirt, metal, concrete, paper, plastics, r other debris.

The species and moisture content are fixed; they are determined by the source. he physical form and cleanliness will depend on the source but can be altered by rocessing. The processing has to be justified by the markets available and the dollar alue that can be realized by upgrading the residues.

Essentially all types of wood residues are now marketable if the supply is within easonable distance of the consuming point and the residues are clean and of the right hysical form.

The greatest potential outlets, by far, are agricultural and fuel uses. All residues in iwdust or shavings are valuable to farmers for bedding and ground control for live- ock. Fuel will be the greatest outlet in the near future since the price of oil is esca- ting rapidly. However, wood residues for fuels require processing to be marketable id to realize their optimum value. Each type of wood burner is designed to handle ood in a specific physical form.

I will define the types of residues by markets and by specifications required of ie residues for processing or use as is (tables 1 and 2).

Wood residues for markets requiring exact processing (fillers for plastics, paper, ir cleaning, and foundries) have to be ground and sized in their applications. Chem- al and physical properties are critical. These residues are usually from secondary wood ianufacture and have exact specifications. These residues have the greatest value but e not typical of urban wood residues unless the governmental agencies involved

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Table 1. Markets requiring exacting processing and specifications for wood residues

End use	Species	Moisture	Physical form	Cleanliness
Woodflour manufacture	Softwood	Under 8%	Secondary residues	Very pure
Paper filler	Softwood	Under 10%	Secondary residues	Clean
Foundry filler	Hardwood	Under 10%	Secondary residues	Clean
Fur cleaning	Hardwood	Under 10%	Secondary residues	Clean
Firelogs	Softwood Hardwood	Under 15%	Secondary residues	Clean

Table 2.—Other markets for wood residues

End use	Species	Moisture	Physical form	Cleanlines
Fuel	Hardwood Softwood Mixed	10–20% Green	Sawdust Shavings Hog fuel Wood chips Sander dust	Bark O.K. Debris & dirt free
Particleboard	Hardwood Softwood	Dry Green	Secondary Residues	Clean
Sewage composting	Hardwood Softwood	Green	Wood chips Total-tree Chips	Debris Free
Agriculture	Hardwood Softwood	Dry or Green	Sawdust Shavings	Clean
Paper	Hardwood Softwood	Green	Wood chips Hog wood	Clean

require industrial wood residues to be considered as part of the urban residue prograr I list these to show the breadth of the residue markets.

A second category includes the major applications of wood residues. Included ar general urban wood residues encountered in disposing of land clearings, packagi residues, dunnage, demolition lumber, tree tops, limbs, and stumps. Essentially all these residues require processing in equipment. Their use requires large volumes ar specific physical forms of residue.

I will define the procedures for marketing residues:

1. Characterize residues according to species, moisture, form, and cleanliness.
2. Determine potential marketing outlets.
3. Locate potential markets within economically feasible shipping range.
4. Determine end use and physical form required.
5. Evaluate against dollar value available.
6. Evaluate costs of upgrade and market.

7. Obtain sales commitments prior to investments.

8. Locate minimum-cost disposal if marketing is not feasible.

Freight costs are the most significant factor in marketing wood residues. Green naterials contain 50 percent water by weight. Shipment beyond 150 miles will usually not be feasible; freight costs will offset the value of the residue.

Specialists in marketing wood residues are available to evaluate residues and provide advice about obtaining optimum dollar value. Specialists include: brokers, state and federal forestry specialists, industrial representatives from papermills, particleboard plants, professional forestry associations (such as FPRS).

Estimated dollar values listed for wood residues are based on the ultimate end use nd processing required. Obviously, the more demanding the specifications, the higher he value and the less supply. In large-volume uses, supply is often abundant and the ollar value is lower.

ESTIMATED DOLLAR VALUE FOR RESIDUES

1. High specifications (exacting processing required):
   (a) grinding and screening ($50-$80/ton delivered),
   (b) secondary residues ($20-$45/ton delivered; dry, clean, specific species)
2. Intermediate specifications (specific physical forms required):
   wood chips, hog wood, species limitations ($18-$35/ton delivered)
3. Low specifications (liberal requirements on physical form):
   sawdust, mixed materials ($10-$18/ton delivered; unlimited species).

I have three case histories of marketing urban wood residues that will illustrate rocessing and dollar value.

The first example is converting pallets, packaging, dunnage, and miscellaneous aste wood from a large industrial plant into hog wood for fuel. This installation is at odak Park, home of Eastman Kodak in Rochester, New York. A small tractor is used crush oversize material such as pallets, and the material is then mechanically scooped and through a hog mounted on the tractor. This procedure allows Eastman Kodak convert waste wood, that is expensive to dispose of, into hog wood fuel worth $20 $30 per ton on a BTU basis when incinerated in a burner producing low-pressure eam for plant consumption.

The second example is improving sewage treatment where green sawdust is used as uel and a filter aid in treating the sludge. This is done in Monroe County, Rochester, w York, with sawdust delivered at $15 per ton in dump trucks and self-unloading t ilers.

The third example is preparing hog wood for pressure fiber processing for paper er. Separated softwood dunnage and packaging residues collected in northern New J sey are hogged to small size and delivered to GAF, Gloucester, New Jersey, for conv sion to a filler for industrial paper. The value of the wood is approximately $25 per t n delivered.

SUMMARY

Marketing wood residues is complex because essentially all end uses require spec fications of some kind on physical form, moisture, and cleanliness. Use of marketin specialists is strongly recommended to obtain the best dollar value and least cost an investment.

SEGREGATION PROCESSES FOR URBAN WASTE WOOD

John A. Sturos[1]

Abstract.—Three technologies—steaming-compression debarking, vacuum-airlift segregation, and photosorting—have been developed for improving the quality of whole-tree and wood-residue chips. Application of these processes coupled with integrated utilization of the various output wood fractions should lower the barriers for increased urban waste wood utilization.

A tremendous underutilized wood resource exists in urban areas in the form of ee removals and trimmings, industrial waste, demolition wood, and secondary manu- cturing residue. In 1976 the total urban wood residue was estimated to be more than 5 million air-dry tons (table 1) (Carr 1978). Demolition lumber alone accounted for 4 million air-dry tons, or 39 percent of the total. One municipality has estimated at it will have to dispose of 10,000 tons of wood per year from diseased trees for e next 8 years, and tree trimmings could be more than 1,000 tons per year from an ban forest of 140 square miles (Ratcliffe 1976).

Table 1.—Estimates of urban wood residue generated in 1976[1]

Source of wood residue	Thousands of tons (air-dry)
Te removals and trimmings	2,820
Emolition lumber	6,410
Plets, containers, dunnage	4,790
Sondary manufacturing residue	2,400
Total	16,410

[1] Carr (1978).

Excluding secondary manufacturing residues, the degree of urban waste wood ulization in 1976 was very low (table 2) (Carr 1978). Only 2 percent, 15 percent, and 3 percent of the demolition lumber, urban trees, and industrial and commercial wood wste, respectively, were used. The remaining wood was either used for landfill or ininerated.

Cities and highly populated counties are currently being forced to process their wod waste because disposal by incineration and/or landfill is no longer acceptable. To irrease urban waste wood utilization, new and improved roughwood processing equip- rnt and methods must be developed to convert these materials to marketable prod- uts. Hopefully this will promote integrated utilization so that each of the various conponents of the urban wood waste can be used for its highest value end use.

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[1]Principal Mechanical Engineer, North Central Forest Experiment Station, Forestry Sciences Laboratory, Houghton, Michigan.

Table 2.–Estimates of urban wood utilization in 1976[1]
(In thousands of air-dry tons)

Use	Urban trees	Industrial, commercial	Demolition waste	Secondary manufacturing residues	Total
Fuel, industrial & residential	280	960		850	2,090
Pulp, composition board	60	240		470	770
Mulch and bedding				480	480
Salvage for lumber			110		110
Saw logs	80				80
Miscellaneous		240		150	390
Landfill or incineration	2,400	3,350	6,300	440	12,490
Total	2,820	4,790	6,410	2,390	16,410

[1] Carr (1978).

Research on improving the quality of whole-tree or wood-residue chips ha resulted in several promising segregation processes. These processes should be con sidered for incorporation into an integrated urban waste wood recovery system. Thi paper discusses these segregation processes.

SEGREGATION PROCESSES

Research on the beneficiation of whole-tree chips or contaminated residual chip at the Forestry Sciences Laboratory of the North Central Forest Experiment Station USDA Forest Service, Houghton, Michigan, has resulted in three promising processes- steaming-compression debarking, vacuum-airlift segregation, and photosorting (Mattso 1975; Arola 1976; Sturos and Brumm 1978). In addition, combinations of the abov processes are possible.

STEAMING-COMPRESSION DEBARKING

The steaming-compression debarking process has been put into practice by Par sons & Whittemore, Inc., who designed and built a debarking plant at one of thei pulpmills. The results of their first 16 months of operation are similar to those obtaine in Forest Service research studies (Wawer and Misra 1977). The basic process consist of three steps: (1) presteaming the unbarked chip mass, (2) passing the chips throug a compression debarker, and (3) screening the compression debarker output to remov bark fines (fig. 1). Additional (optional) steps include mechanical attrition of th smaller chip output fractions followed by screening to remove additional fines.

In cooperation with Urban Wood and Fiber Products, Inc., steaming-compressio debarking of elm chips was evaluated (table 3). Results indicate that 66 percent of th bark was removed and 85 percent of the wood recovered with a final bark content i the accept fraction of 3.1 percent. By including only the +3/8-inch-size chips in th accepts, the bark content decreases to 1.6 percent but yet more than 60 percent of th wood fiber is recovered.

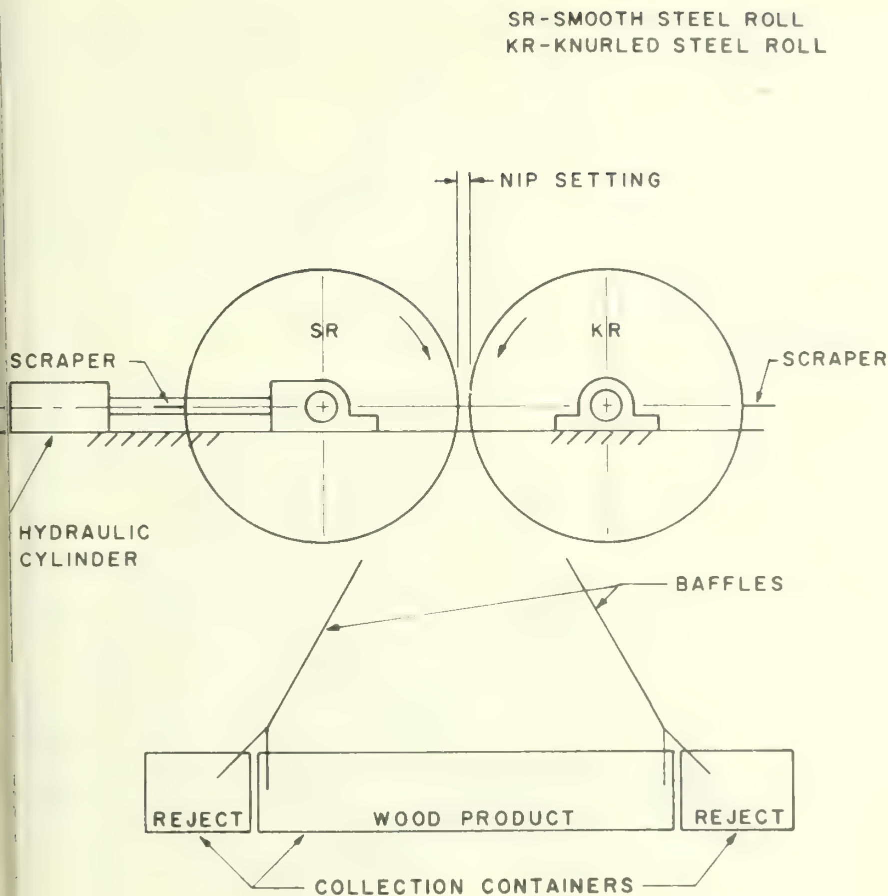

Figure 1.–Compression debarker.

Table 3.–Results of steaming-compression debarking of elm chips[1]

Product	Input material	Bark content	Total wood	Total bark
		Percent		
Accepts				
+3/8" fraction	57.7	1.6	61.4	12.3
-3/8 + 3/16" fraction	23.6	6.9	23.7	21.6
Combined accepts	81.3	3.1	85.1	33.9
Rejects	18.7	26.4	14.9	66.1
Input	100.0	7.5	100.0	100.0

[1] Chips supplied by Urban Wood and Fiber Products, Inc.

VACUUM-AIRLIFT SEGREGATION

The vacuum-airlift segregator has received laboratory scale testing both by th USDA Forest Service and by industry. It consists of a wire mesh conveyor belt wit vacuum hoods placed above the belt at various stations (fig. 2). Whole-tree chips a spread over a continuously moving conveyor belt that passes through fields of a currents that subject the chips to vacuum forces from above the belt. The material then segregated on the basis of differences in terminal settling velocities caused b density and geometric differences. Typically, in a multiple-stage system, foliage, clea wood chips, and "middlings" are removed at different locations along the belt. Bar knots, and twigs remain on the belt to discharge to a "reject" product area, and fines bark, some foliage, dirt, and grit fall through the mesh belting.

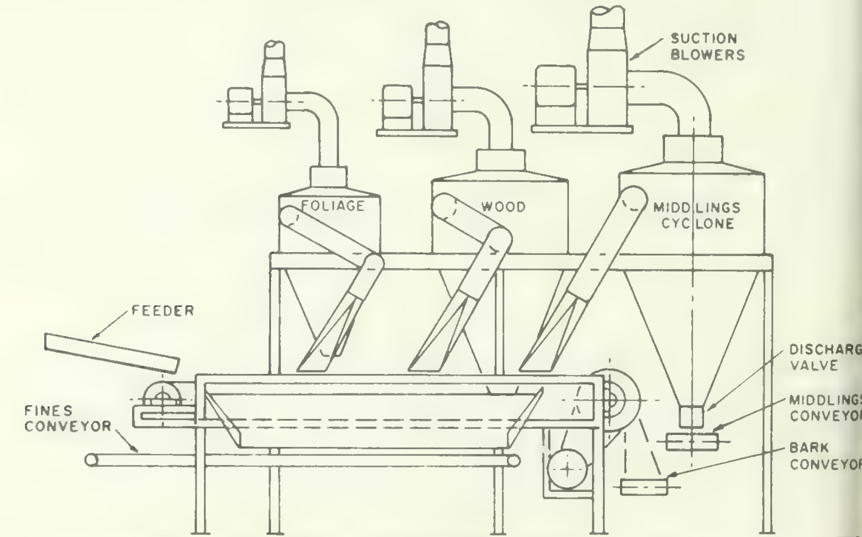

Figure 2.–Multiple-stage vacuum-airlift segregator. Fines fall through the wire mesh conveyor.

The "middlings" fraction contains from 30 to 50 percent of the total inp material, depending on species, and has a bark content equal to or higher than the received whole-tree chips. This fraction can be used for pulp, particleboard, fuel, chemicals. If the middlings are to be used for pulp, further beneficiation by compression debarking process is recommended.

For maximum recovery of "clean" fiber, a combined system is recommen (fig. 3) (Sturos 1978; Sturos and Marvin 1978). It consists of vacuum-airlift segre tion followed by steam-compression debarking of the middlings fraction (table fig. 4). By means of the vacuum-airlift stage, 4 percent of the input is removed as co mercial foliage, 4 percent falls through the wire mesh conveyor as fines, 42 percer recovered as clean wood chips acceptable for pulping, 36 percent is recovered as m dllings, and 14 percent is left on the conveyor as bark (fuel). Passing the middli through the compression debarker results in an additional 29 percent clean w

hips and 7 percent bark. The combined product recovery results are 71 percent iber, 25 percent fuel, and 4 percent foliage.

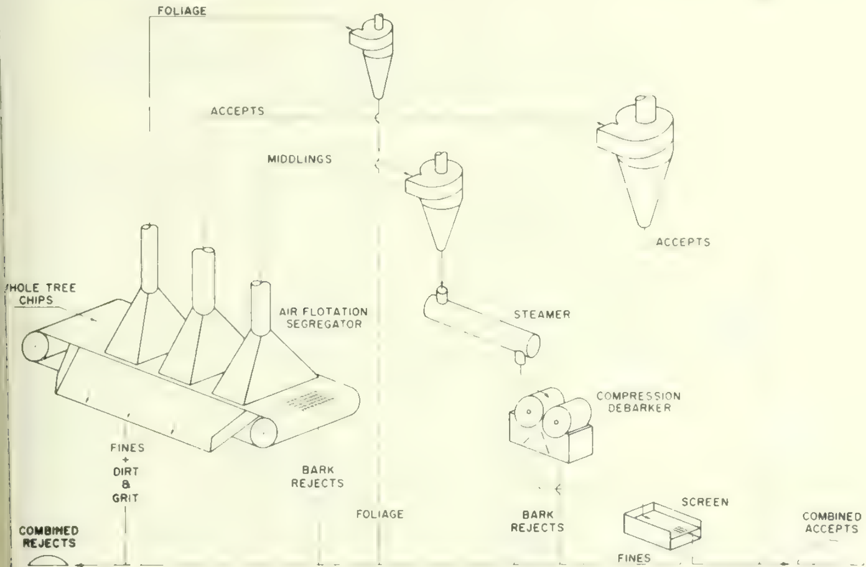

Figure 3.—Combined vacuum-airlift and compression debarking system for beneficiating whole-tree chips.

Table 4.—Typical foliage and bark removal results obtained by combining the vacuum-airlift and compression debarking processes[1]

Process and components	Aspen	Sugar maple	White birch
		Percent	
Vacuum-airlift segregation:			
Input bark content	20.2	13.2	16.4
Bark content	4.8	5.7	7.6
Wood recovery	52	37	40
Bark removal	51	41	45
Foliage removal	84	85	94
Vacuum-airlift & compression debarking:			
Input bark content	20.2	13.2	16.4
Bark content of accepts	5.3	5.3	5.9
Wood recovery	88	87	87
Bark removal	80	69	73
Foliage removal	86	86	94

[1] All calculations are based on dry weight.

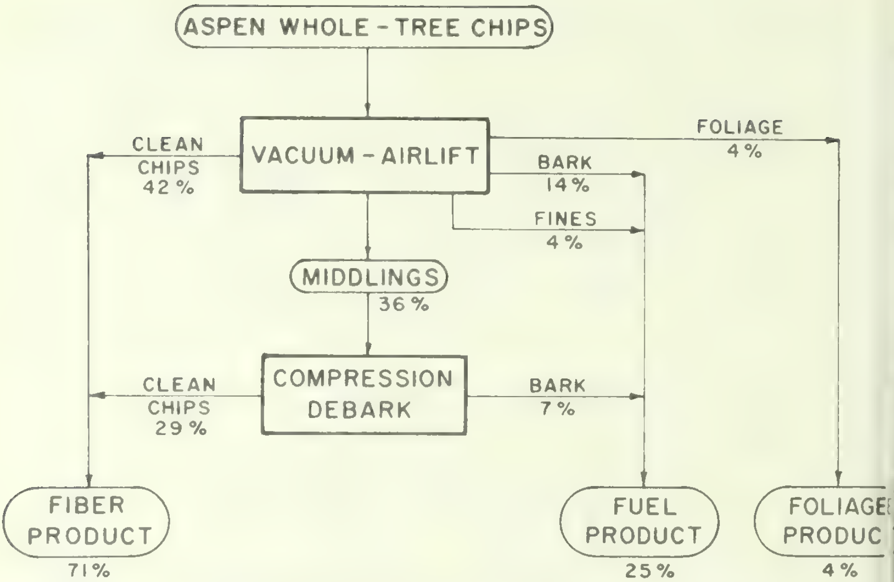

Figure 4. End products and intermediate steps in segregating aspen whole-tree chips.

PHOTOSORTING

Wood and bark chips differ sufficiently in their optical transmittance to be sorta When photosorting, the chips are fed by a conveyor over a linear array of op detectors (fig. 5). Light from an incandescent source is incident on the chips f above. The light intensity is adjusted such that most wood chips transmit suffic light to be sensed by the detector array. When a bark chip passes over the detec the transmitted light falls below a preset detection threshold and the detector ph current decreases. The resulting signal is amplified to energize an air valve, w deflects the bark chips with a blast of air (fig. 6). Preliminary results for 5/8-inch a chips are promising (table 5). Depending on light level, bark content of 1.4 and percent with corresponding wood recoveries of 70 and 96 percent are possible.

ECONOMICS

The Forestry Sciences Laboratory has conducted several cost analyses of steaming-compression debarking system, the vacuum-airlift system, and combinat of these two systems. They have revealed that the combined system is the most efficient. One of the primary advantages of coupling the vacuum-airlift segregator the compression debarker is to reduce capital equipment cost and consequently, t ficiation cost. This decreases the amount of material the compression debarker h process, which in turn reduces steam requirements, the size of the press, and there cost. The beneficiation costs (1978 basis) range from about $6.70 per output dry of "clean" chips for a steaming-compression debarking system to $4.70 for a c bined system in which only 34 percent of the material is compression debarked. T capital investment for a 60 ton per hour debarking plant ranges from about $3 mi

or a steaming-compression debarking plant to $1.7 million for a combined vacuum-irlift and steaming-compression system.

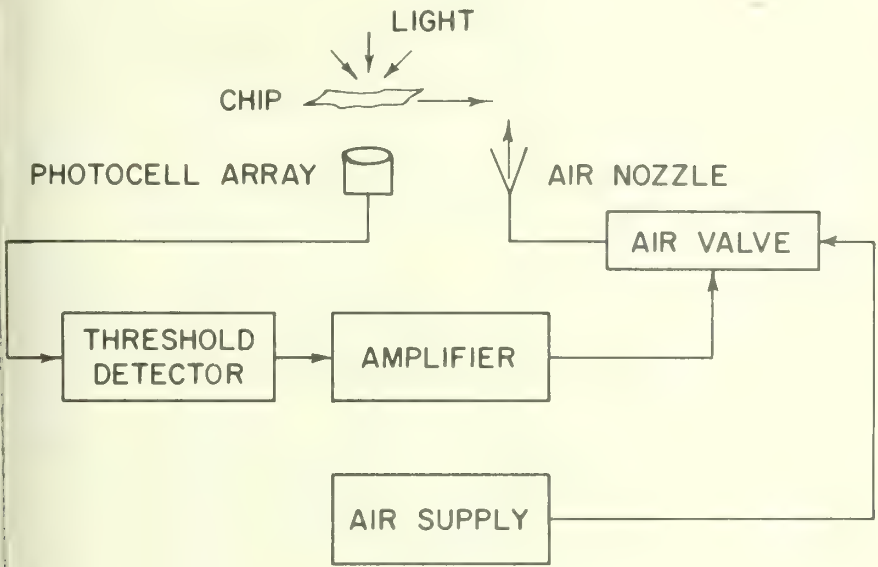

Figure 5.–Photosorting system diagram.

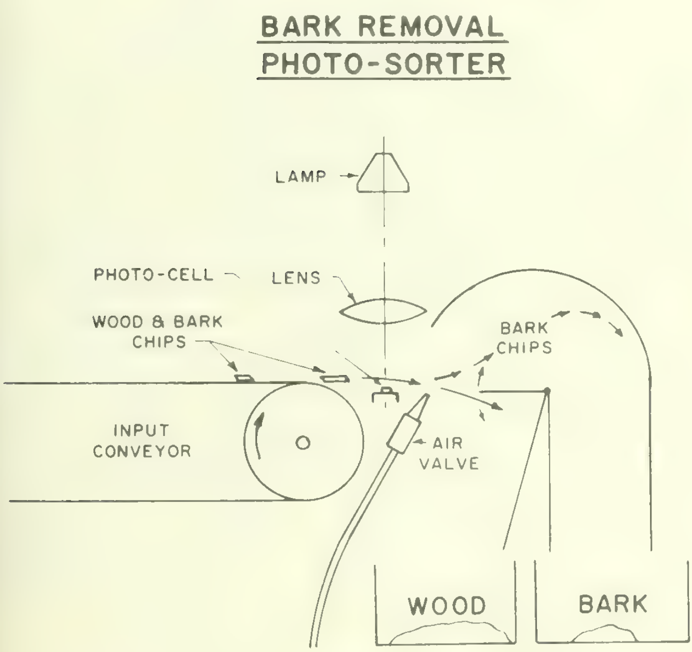

Figure 6.–Mechanical configuration of the photosorting system.

Table 5. Effect of light level on photosorting 5/8-inch aspen wood and bark chips
(In percent)

Product	Bark content	Portion of total chips	Portion of total wood	Portion total ba
	LIGHT LEVEL – 2.5 mW/cm			
Input	10.6	100	100	100
Accepts	1.4	63	70	8
Rejects	26.2	37	30	92
	LIGHT LEVEL – 3.5 mW/cm			
Input	9.3	100	100	100
Accepts	2.3	79	86	19
Rejects	36.7	21	14	81
	LIGHT LEVEL – 4.5 mW/cm			
Input	8.9	100	100	100
Accepts	3.3	88	93	32
Rejects	48.5	12	7	68
	LIGHT LEVEL – 5.5 mW/cm			
Input	9.7	100	100	100
Accepts	5.1	91	96	48
Rejects	56.4	9	4	52

A typical urban wood waste recovery plant includes a number of processing such as crushing, washing, hogging, screening, and magnetic separation (fig. 7). and where would a vacuum-airlift segregator be incorporated into such a rec plant? A three-stage segregator is one possibility (fig. 8). It would be one of th stages in the total material flow through the plant (fig. 9) resulting in at least fractions of wood chips high-quality chips and fuelwood chips. Cost to ins 20-ton-per-hour vacuum-airlift segregation system (fig. 8) into an already existing has been estimated to be $175,000. The processing costs would be less than $ input ton. Total connected horsepower is 205.

SUMMARY

Three new systems have been developed for upgrading the quality of whol and wood residue chips -steaming-compression debarking, vacuum-airlift segreg and photosorting. A combined system using steaming-compression debarking vacuum-airlift segregation has proved to be the most economical for maximum fiber recovery and the vacuum-airlift segregation system can easily be incorpo into present waste wood recovery, systems. Installation of a 20-ton-per-hour sy is estimated to cost $175,000. With the large number of energy products, chem and fiber products that are potentially available from waste wood, we are at the step of converting it from a disposal problem to a valuable resource.

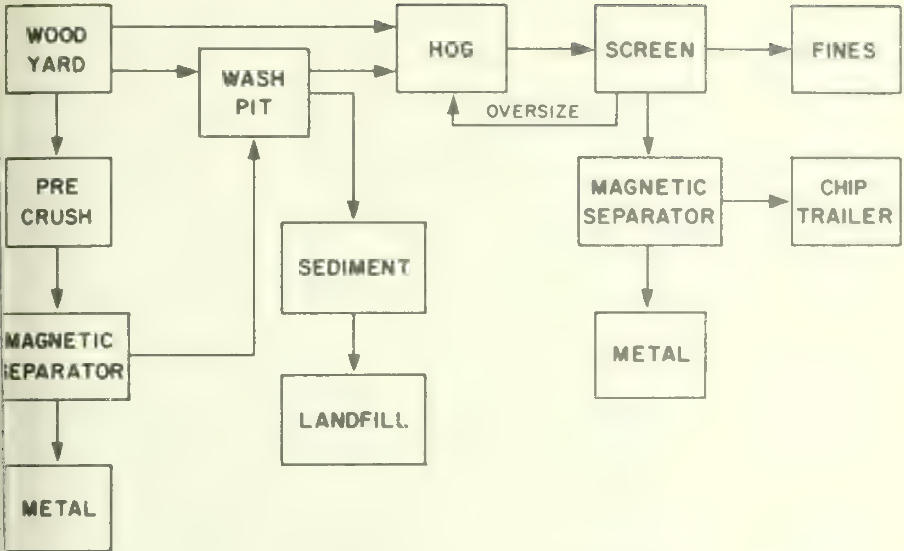

Figure 7.–Typical urban waste wood recycling plant.

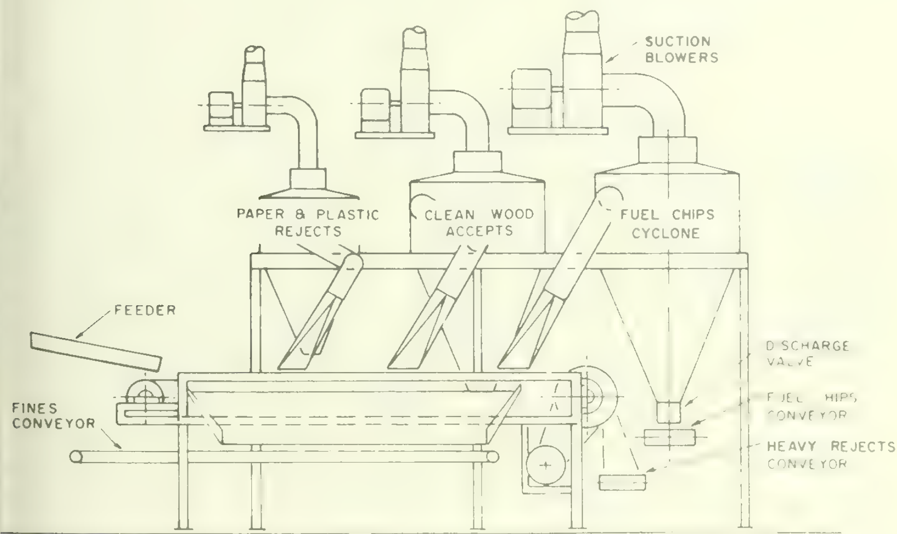

Figure 8. A three-stage vacuum-airlift segregator for urban waste wood recovery.

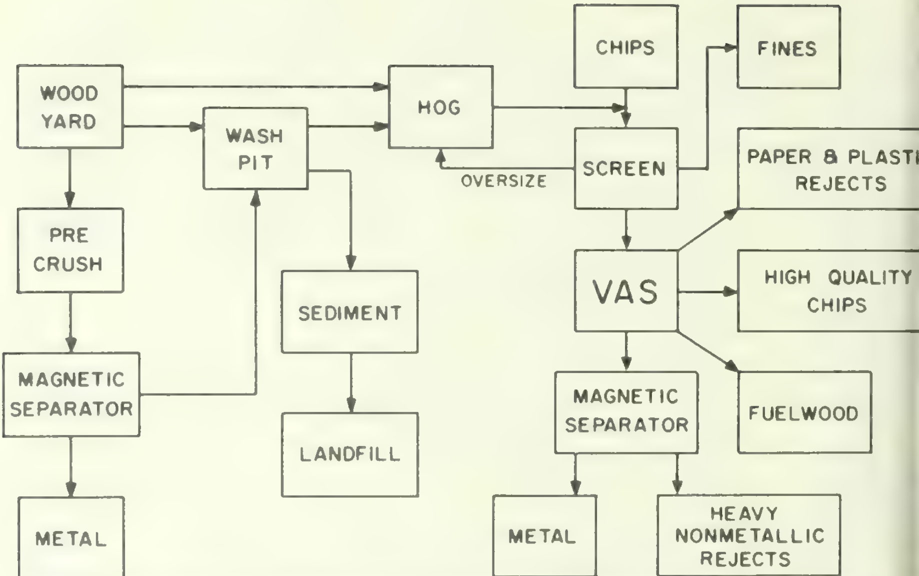

Figure 9.–Proposed urban waste wood recycling plant including vacuum-airlift segregation (VA

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IMPORTANCE OF WOOD AS AN URBAN ENERGY SOURCE

James W. McMinn[1]

Abstract.—The paper reviews (1) theoretical limits to wood supplies, (2) characteristics of wood as a fuel source, (3) difficulties in predicting energy consumption and fuel prices, and (4) the outlook for wood-energy development. Woody biomass is likely to provide less than 10 percent of urban energy, and its use will be in small-scale, decentralized systems. Small towns will derive the greatest benefits from primary biomass, whereas use of urban waste wood will probably be unrelated to city size.

Energy consumption in the United States has increased almost twentyfold in the last century. During the same period, the amount of energy the Nation derives from wood has decreased to a little more than a third of its former contribution. At one time, 75 percent of our energy was supplied by wood, whereas it presently supplies well below 5 percent (Curtis 1978). A large proportion of the national energy supply will probably never again be derived from wood, but use of wood for energy could be substantial in certain areas. This presentation covers (1) theoretical limits to wood supplies, (2) some advantages and disadvantages of wood as an energy source, (3) some complexities inherent in projecting fuel use and prices, and (4) future possibilities for wood-energy development.

WOODY BIOMASS SUPPLY

In determining quantities available for conversion into energy, annual growth rather than the total wood volume in the forest must be considered. Professional foresters routinely base estimates of possible use on growth, but individuals not involved in renewable-resource management often fail to recognize the distinction between mining an inventory and harvesting growth. Estimates of total growth over a large geographic area are not sufficiently precise for an individual or firm that is seriously considering wood as an alternate fuel. However, such estimates are valuable to planners and policymakers for placing upper limits on wood harvests for all purposes. Some of the more reliable estimates follow.

Worldwide, plants store about six times as much energy in biomass as humans use each year (Dubos 1976). More than half of this biomass is produced in forests that receive no more than custodial management. Less than one-tenth of the annual biomass accumulation occurs on cultivated areas, so their current energy potential is quite low when energy inputs are accounted for.

In contrast to the world situation, annual biomass increment in the continental United States is equivalent to only about half the energy consumed (Burwell 1978). Furthermore, this biomass includes food, fiber, and feed grains as well as forest and crop residues and surplus increment. Woody biomass growth on our commercial

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forestland is equivalent to somewhere between 10 and 15 percent of our annual energy consumption. The United States ratio of biomass accumulation to energy use represents a prodigious rate of consumption, rather than a low level of productivity.

The foregoing figures do not mean that wood fuels are impractical or insignificant. They do mean that on a national or regional scale there are definite limits to the role wood can play in supplying energy for urban areas.

In many places, wood can be a very practical source of energy. One plant in France has generated electricity from wood-fired boilers for over 50 years (Jagles 1978). In Maine, Vermont, and New Hampshire, 18 percent of all households use wood as their primary heating source, and citizens of Burlington, Vermont, have approved a $40-million bond issue for a 50-megawatt wood-fired power plant (Anon. 1979). Burlington currently has a 30-megawatt plant supplied by three 10-megawatt boilers; one of those boilers has operated successfully for several months on wood. A recent study indicates that a 25-megawatt wood-fired plant would probably be feasible in north-central Minnesota (Rose and Olson 1979). The wood-products industry currently derives over 30 percent of its energy from waste wood.

The pertinent question, then, is not whether wood energy is feasible, but where and on what scale. Approximately half of the biomass growth on our commercial forestland occurs in the southeastern quarter of the country (Burwell 1978), so it is probable that substantial development opportunities exist here. The Southeastern Forest Experiment Station's wood-energy research unit at Athens, Georgia, is developing procedures to identify communities with high development potential and to determine the degree to which development in one community will constrain development in others. We are focusing on physical supply and will be dealing with several supply variables, beginning with sawmill residues presently generated and working ultimately with the long-term productive capacity of the land. We do not include urban wood waste, primarily because reliable inventory data are not available. Urban areas may produce waste wood at a rate equivalent to 23 percent of the growth on commercial forestland (Burwell 1978). If so, this source of energy would be significant in many communities.

WOOD AS A FUEL SOURCE

Since 1974 wood-energy development has been surprisingly slow in light of the interest and available technology. Some of the disadvantages of wood as a fuel source explain the limited development.

Woody biomass is quite variable, and its energy is less concentrated than that in other common fuels (Jagles 1978). It is therefore difficult to handle and costly to transport, and it requires a relatively large amount of storage space for a given burner output. The most difficult problem, however, is water content. The energy equivalent of green wood is less than half the 8,500 BTU per pound of dry wood.

Biomass is one of several potential energy sources derived from the sun. Solar energy in any form has broad appeal because, in theory, it is freely available and the worst forms of pollution are not associated with its use. However, practical application of solar energy requires capture and storage. Plants perform both functions. They capture less than 5 percent of total insolation, but they do so at low cost. Woody plants

e particularly attractive as energy sources because, unlike annual plants, they can cumulate energy for many years before harvest. Large quantities of fuel, therefore, n be harvested per unit area. Burwell (1978) has shown that ratios of energy output/ put can be relatively high (35–40/1) for unmanaged forestland because the only put required is for harvesting.

Some investigators have concluded that the net effect of the above advantages and advantages will lead to small-scale, decentralized conversion of woody biomass to ergy (Dubos 1976; Burwell 1978). This conclusion seems to imply that opportunis for wood-energy development will be more numerous for small towns than for ge urban areas. However, urban waste wood differs from other woody biomass in o important respects: (1) some of it is at least partially dry, and (2) it is already ntralized to a degree. Some of the costs associated with wood-fuel transportation d processing are, therefore, borne by other products.

ENERGY COST COMPARISONS

There are many uncertainties associated with predicting the relative costs of wood d alternate energy sources. In the absence of operational experience, costs of harsting, concentrating, and/or separating types of material can be only roughly estited. Furthermore, changes in energy supplies and costs can be predicted only with at uncertainty.

On the basis of Carter's (1974) discussion, the uncertainties may be grouped under h following categories:

Waste trimming.–Decades of inexpensive energy have led to waste that conseraon efforts can reduce at little or no cost. More leeway probably exists in space ating and lighting than in industrial processes.

New technology.–Notable examples of energy-saving technology are new processs for manufacturing steel and aluminum, but advances are taking place in many ields and at all scales of use.

Implementation of existing technology.–No new technology is needed for carooling, widespread use of mass transit, or for efficient recycling of many energyxensive materials. As energy costs rise, greater economic incentives should force mlementation of known technologies.

Labor-energy substitution.–From World War II until the 1973-74 oil embargo, engy costs decreased and labor costs increased. The benefit of energy substitution eme axiomatic. With energy costs increasing faster than labor costs, that axiom no oner holds. We can now expect a gradual substitution of labor for energy.

Schipper and Lichtenberg (1976) have demonstrated how some of the above acors influence Sweden's rate of energy consumption compared to that in the ned States. They found the main contributing factors to be ". . . smaller automobil, more use of mass transit, more insulation and tighter construction, more efficient ndstrial processes, and the use of cogeneration and district heating." Of these factors, nd district heating varies substantially from near-term United States capabilities: in Swlen, waste heat from power stations is distributed throughout rather large districts or pace heating. A high standard of living is commonly thought to depend on high

energy consumption. Swedish energy consumption per unit of Gross National Prodı is only 68 percent of that in the United States, and the two countries have genera comparable standards of living. A policy-study group here in the United States h concluded that it will be ". . . technically feasible in 2010 to use roughly a to amount of energy as low as that used today and still provide a higher level of ame ties, even with total population increasing 35 percent" (Demand and Conservati Panel of CONAES 1978).

FUTURE OUTLOOK

Most authors dealing with energy agree that use of oil and natural gas will decli and that in the short term no single large energy source will replace them. The varie and character of alternate energy sources will probably force a trend toward mc individually tailored systems, rather than uniform, energy-wasteful systems (Jag 1978). This environment will be conducive to wood-energy development. It could al lead to depletion of wood supplies and increased fuel transportation costs for loc areas.

For the longer term, Hayes (1979) builds a logical case for the likely developme of coal as the single large energy source in the United States. He points out that pub opposition, increasing capital costs, and decreasing growth in electrical energy use a recognized as obstacles to nuclear development, but the availability of uranium is more significant restriction than is generally realized. If coal use increases rapidly, t combustion of wood with coal is potentially significant for maintaining sulfur em sions at acceptable levels (Inman 1977).

Energy plantations can have a favorable energy output/input ratio and could full some of our long-term energy needs (Inman 1977). However, they have definite lin tations and are no panacea for energy problems. One of the greatest fallacies associat with energy plantations is the emphasis on so-called fast-growing species. Plant grow is a result of genetic capacity and environmental conditions. The only differen between fast-growing species and slow-growing species is that the former have t capacity to respond to a rich environment and the latter do not. Therefore, fast-growi species do not grow fast on marginal land. Phenomenal production is possible throu fertilization and irrigation of marginal lands, but these operations are energy-expensiv Current research efforts are comparing outputs with inputs for such situations. Citi close to marginal lands have a unique opportunity to coordinate waste manageme and energy production by using ash and sewage as soil amendments to increase prodı tion on biomass plantations.

CONCLUSIONS

Wood can be expected to supply less than 10 percent of the energy for urb areas, but its contribution could be substantially greater in selected communities.

Generalizations about the relative costs of wood and other fuels are extreme difficult to make.

Most systems for conversion of wood to energy will probably be small, decentra ized, and tailored to local conditions.

Because of high transportation costs, small towns are most likely to use forest-own wood for energy.

Since urban waste wood must be concentrated for disposal even if it is not used, nsportation need not be considered in estimating cost of converting this wood to ergy.

Biomass plantations will probably play a limited role in energy supply, but some an areas have unique opportunities to develop innovative energy plantation systems.

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RECOVERY OF ENERGY FROM SOLID WASTE– AN ALTERNATIVE TO LANDFILL DISPOSAL

Gloria A. Mills[1]

Abstract.–There are many solid waste recovery techniques from which communities may choose. The technology described here is known generally as mass combustion in waterwall boilers. A facility using this technology takes all kinds of residential, commercial, and nonproblem industrial solid wastes and processes them into usable energy and marketable materials. This combustion process performs extremely well, with better than 96 percent burnout of combustible matter and a volume reduction of 95 percent.

Pinellas County, Florida, located on the west coast between the Gulf of Me and Tampa Bay, is primarily an urban area, having as its two largest municipalities cities of St. Petersburg and Clearwater; in fact, it is the most densely populated cou in the State. Pinellas County faces a problem encountered by many other urban ar how to dispose of its solid waste in an environmentally acceptable manner at a t when disposal costs are rising and landfill space is diminishing.

The county took a number of steps to reduce its waste collection costs an improve productivity. It switched to hydraulically operated packer trucks and man collection vehicles. A variety of factors, including the limited future life o largest landfill, led to a search for an alternative to that method of disposal.

An act of the Florida legislature gave the Board of County Commissioners responsibility for the disposal of all solid waste throughout Pinellas County. same legislative act established the Solid Waste Technical Management Commi (TMC). Members are technically qualified representatives from designated munici ties. The TMC has been instrumental in providing guidance to the Board of Cou Commissioners in the development of a solid waste program for the county.

The program began with the selection of Henningson, Durham, and Richard (HDR) as the county's engineering consultant and William R. Hough & Co. as county's financial consultant. Both firms are nationally recognized experts in de oping programs for solid waste disposal.

HDR conducted a feasibility study to determine how much and what kind wastes existed in the county, what technological alternatives existed for the disp of those wastes, what markets existed for the energy and materials recoverable f the waste stream, and what sites were available for the location of a resource reco facility. The results of the study indicated that resource recovery was feasible, ar plan for the implementation of a resource recovery system was developed.

The plan had three major objectives. The county wanted a system that (1) technically sound, (2) environmentally acceptable, and (3) economically acc

[1]Marketing Engineer, Solid Waste Systems, UOP, Inc., Des Plaines, Illinois 60016.

ple. Private firms were invited to indicate their interest in contracting for the disposal f 12,000 tons per week of the county's waste. Following an initial prequalification ocess, seven of the largest and most experienced companies in the solid waste busi-ess were invited to submit proposals for a total resource recovery system. The six oposals actually received were subjected to a detailed evaluation that included the e of computers to process cost data and provide sensitivity analyses. An extensive scription of this Request for Proposal (RFP) process can be found in an article by r. D. F. Acenbrack, Director of Solid Waste Management for Pinellas County.[2] The sult of the evaluation was the selection by the County Commission of the proposal ceived from UOP, Inc.

UOP, formerly Universal Oil Products Company, is an international high-technol-y firm with more than 60 years of experience in commercializing new technology, th emphasis on energy and the environment. In addition to resource recovery, UOP involved in petroleum refining, chemicals and petrochemicals production, water rification, air pollution control, minerals processing, process engineering, and con-uction and manufacture of high-technology products.

The technology to be utilized in the Pinellas County resource recovery facility, ich will be designed, constructed, and operated by UOP, is in the category known nerally as mass combustion in waterwall boilers. UOP has a long-term agreement th the Josef Martin Company of Munich, West Germany, to market their extensive mbustion technology in the U.S. and elsewhere.

The facility proposed for Pinellas County, and shown in the artist's rendering (g. 1), will contain two combustion trains and will accept all kinds of residential, mmercial, and nonproblem industrial wastes and process them into usable energy ad marketable materials. As there are presently no suitable energy customers in the mediate vicinity of the facility site, the sole energy product will be electricity, which vl be purchased by a public utility, the Orlando Utilities Commission.

Figure 2, a simplified schematic drawing, shows how the facility works. Collection vhicles, after being weighed at the entrance, drive into the processing building where ty unload directly into a large receiving pit. Once unloaded, the trucks exit from the pocessing building and are quickly on their way.

Except for bulky wastes, the unsorted refuse is picked up by overhead cranes and tansferred to the furnace-feed hoppers. Bulky refuse, including tree trunks and furni-te, is first reduced in size, then processed with normal waste materials. The size reuction is accomplished with a shear-type device to get these larger items down to abut a 1-foot dimension.

Part of the air needed for the combustion process is drawn from the area above tl refuse receiving pit, which accomplishes two things. First, it creates a slight nega-ti pressure, which prevents dust and odor from escaping to the outside; second, it d ws airborne bacteria and dust from the pit area into the furnace where any bacteria a destroyed. Personnel working in the pit area are thus supplied continually with fsh, clean air.

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[2] Acenbrack, D. F. 1978. Tools and team expedite resource recovery project. Public Works M (Oct.)

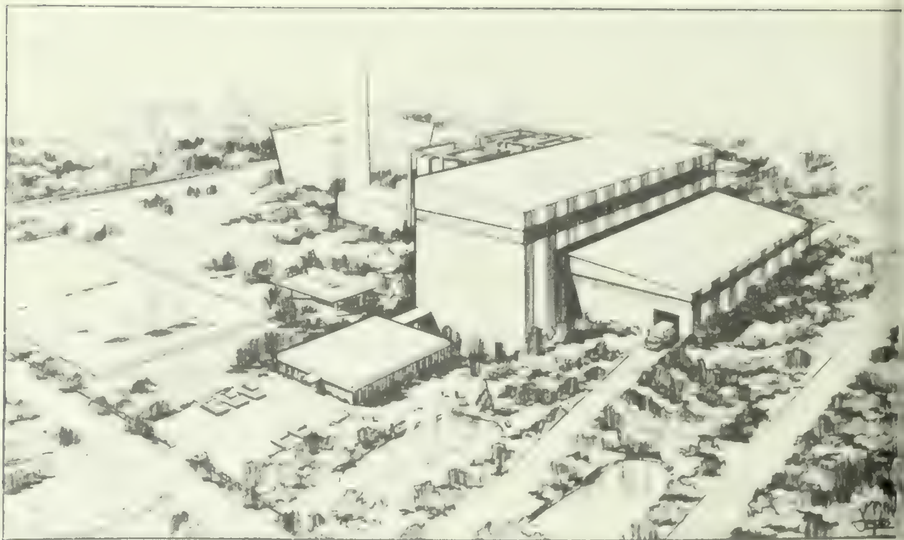

Figure 1.–Pinellas County resource recovery facility.

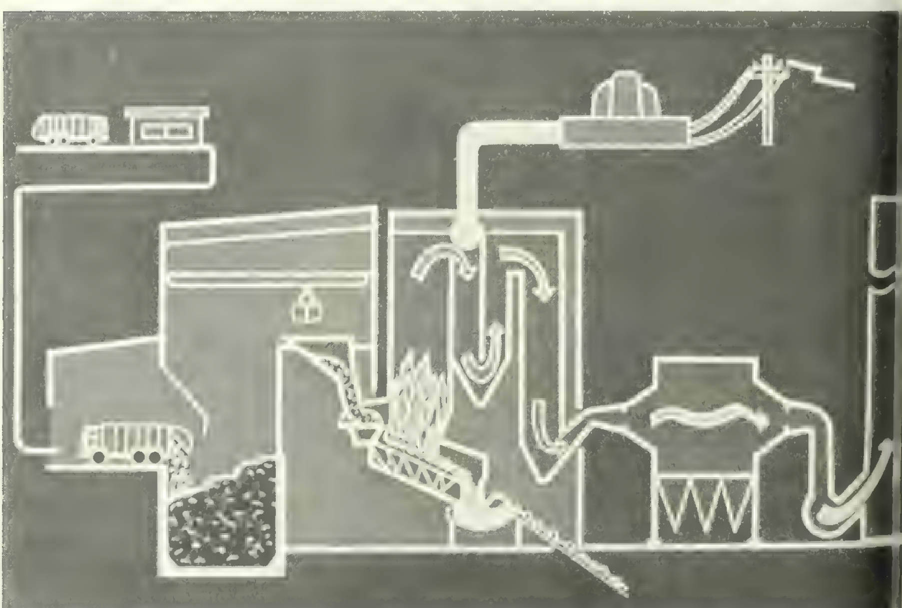

Figure 2.–UOP resource recovery system.

Once loaded into the feed hopper, the refuse passes down through a water-acketed feed chute from which it is metered onto the stoker grate by means of hydrau-ically operated feeder rams. The Martin reverse-reciprocating stoker is one of the fea-ures that make this resource recovery system unique (fig. 3).

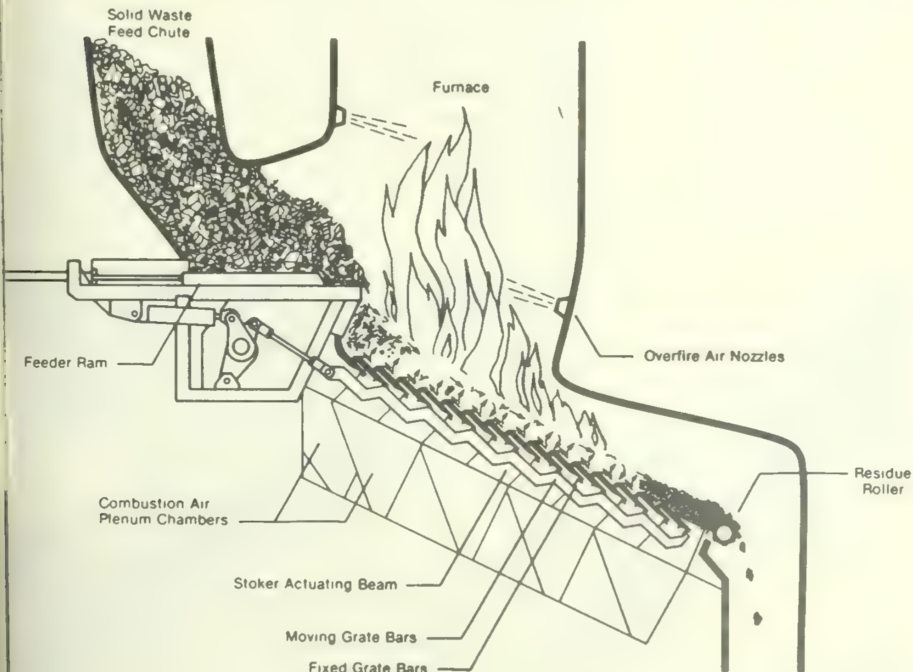

Figure 3.–Martin reverse reciprocating stoker.

As can be seen in the schematic drawing, the Martin reverse-reciprocating stoker is like conventional stoker designs. It is inclined downward toward the discharge end d is divided alternately into fixed and moving rows of grate bars. The moving grates sh upward against the natural downward gravitational movement of the refuse. This ovement agitates the burning refuse to form an even depth over the fuel bed. Burning fuse is pushed back underneath the incoming raw refuse to achieve continuous dry-g, volatilization, ignition, and burning. The result of this unique agitation is a uni-rm burnout of better than 96 percent of the combustible matter.

A series of plenum chambers underneath the stoker grate admits combustion air i volumes controlled to suit the combustion conditions of each burning zone. With t use of preheated combustion air, thorough burnout is achieved even when process-i wastes high in moisture content. No manual cleaning of the undergrate plenums is quired because an automatic siftings-removal system periodically sweeps the plenums.

A series of overfire air nozzles, located in the front and back of the furnace-thr area, provides maximum flame turbulence and prevents the stratification of gasses.

The speed of the residue roller is independently controllable to regulate the de of the fuel and ash layer on the grate. The ability to control the feed rate of ref into the furnace, to control the agitation and depth of the refuse bed on the stol and to control the volume and distribution of the combustion air is a key to unmatched performance of this combustion system.

The grate bars themselves are also unique. A close-up view of the grate bars sh the 2-mm airgaps at the heads of the bars (fig. 4). These airgaps represent only 2 cent of the total-grate surface area. High-pressure combustion air passing through th gaps causes intense burning, even of dense materials like carpeting, and minim sifting of ash through the airgaps. The precision-ground grate bars are cast of dur chrome-alloy steel for long operational life.

Figure 4.—Martin grate bars.

A furnace interior shows the modular approach to unit design. The stoker con of multiple longitudinal grate sections across the width of the furnace. Larger u contain several grate sections, while smaller units contain fewer. The boiler furna constructed of gas-tight, continuously welded waterwalls down to the grate surf These waterwalls are coated with refractory material above the grate surface to a he of about 20 feet. The refractory has good heat-transfer characteristics and prev corrosion in the lower section of the furnace where high temperatures are enc tered. The large volume of the furnace above the throat area is designed for low velocities to avoid high fly-ash carryover to the gas-cleaning equipment and exce slagging in the boiler.

The boiler, which is integrated with the furnace, is also specifically designed for efuse combustion. Boiler tubes are arranged in widely spaced rows, not staggered, to ermit effective cleaning by sootblowers and to prevent plugging of tube rows. The nultipass design of the boilers reduces the particulate load into the gas-cleaning equip-nent as the reversal of the gas flow at the bottom of each pass causes particulates to lrop out of the gas stream. The superheater is strategically located away from the adiant furnace zone in an open pass. This location requires a larger superheater urface area but has resulted in a recorded operating life of more than 40,000 hours vithout tube replacement. The steaming conditions at the Pinellas facility will be 15 psig., 750°F.

Combustion gases from the boiler pass through an electrostatic precipitator for emoval of particulates before the gases are released to the atmosphere through the tack. This equipment is also designed to accommodate fly ash. The precipitators pro-osed for this facility contain three electrical fields, which will keep emissions below urrent standards. Provision has been made in the design, however, for the installation f a fourth field in the event that emission requirements become more stringent in the uture.

The steam produced in the boiler is used to drive a turbine-generator to produce ectricity for sale. A portion of the steam is also used in-house to drive some of the quipment. The whole operation is monitored from an air-conditioned central control oom.

Conceptually, the UOP materials recovery system begins on the Martin stoker ate where combustible material that might hamper recovery efforts is completely urned out. The precise distribution of underfire combustion air prevents combustion hot spots" that could damage or destroy recoverable materials.

The combustion residue is discharged from the furnace into residue dischargers. ere, the residue is quenched in water which also serves as an air seal to prevent akage of uncontrolled combustion air into the furnace. The residue is cooled below 12°F by the quench water and is pushed, by a discharge ram, up into a draining and ying chamber. The discharged residue contains just enough moisture to control ıst, which permits the use of ordinary conveyors to transport the residue to the aterials recovery system.

Materials recovery, as seen in the simplified schematic (fig. 5), is essentially a ries of sizing and separation processes to separate the metallic from the nonmetallic sidue and to separate the ferrous from the nonferrous metals.

Bulky ferrous and nonferrous scrap is the first item separated for sale. A rotating ommel screen divides the remaining stream into two fractions, one larger than inches and the other smaller than 2 inches. The plus-2-inch fraction, which is pri-arily "tin" cans, will pass a magnet for ferrous removal. This ferrous material is then redded to remove surface contamination and to increase the density of the metal ior to sale.

Material less than 2 inches will also pass a magnet where small bits of ferrous metal ll be removed. The remainder will be primarily aluminum, heavy nonferrous metals, ıss, ash, and other inorganic materials.

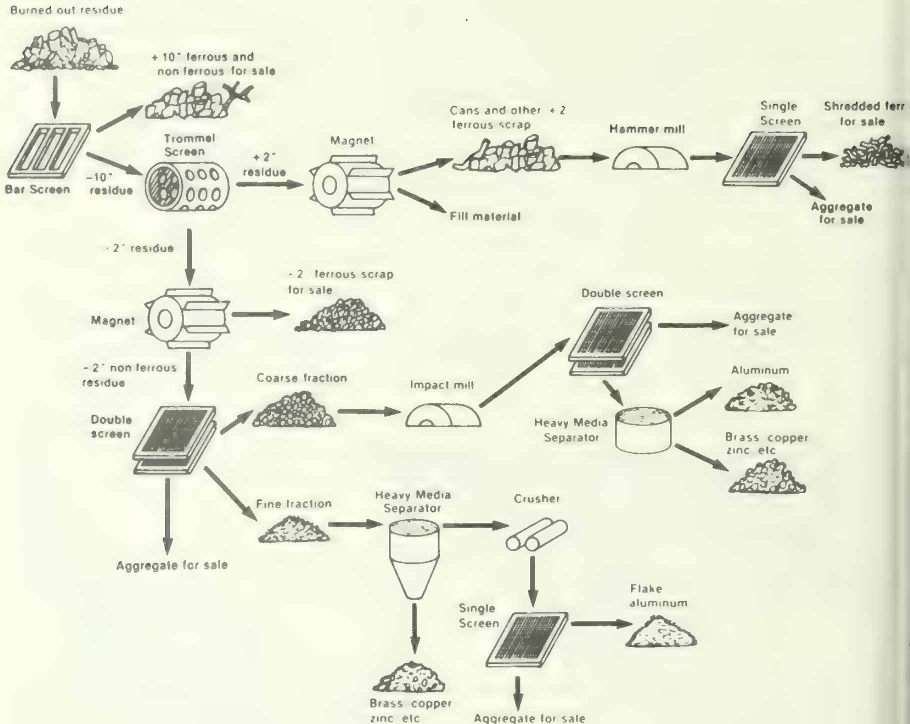

Figure 5.–UOP materials recovery system.

Additional screening will subdivide the stream into coarse and fine fractio removing most of the glass, ceramics, dirt, and other nonmetallic particles. Alumin and other nonferrous metals will be recovered from each fraction by heavy-me density separation. Because of the difference in specific gravity, aluminum will fl while zinc and copper alloys sink. Small aluminum particles will be crushed into rec erable flakes.

The crushed glass, ceramics, dirt, and other nonmetallic particles removed dur this sizing process may be admixed with the precipitator fly ash, which is collec separately. This aggregate material may be sold and used as supplemental aggregat asphalt paving mix, in roadbed construction, as landfill cover, and as fill for l reclamation.

After recovery of metals and aggregate material, the remaining stream will con primarily of larger stones, bricks, and similar noncombustible and nonmetallic obje This stream will generally be the only residue. Although it may have value as clean it will usually be disposed of in a landfill. This process residue will represent about percent, by weight of the incoming raw solid waste.

The Pinellas County facility will operate 24 hours a day, 7 days a week. Each of ie two combustion units is scheduled for shutdown for inspection and maintenance vice a year. The plant's 50 MW turbine-generator is scheduled for shutdown and spection every 3 years.

To minimize use of potable water, a precious commodity in Florida, effluent from tertiary water treatment plant will be used in the cooling towers of the resource covery facility.

The resource recovery plant will be centrally located within the county for service all county communities. UOP has allocated funds for landscaping and site beautifi- tion so that the facility will be attractive.

Applications for required Federal and State permits covering air emissions and owerplant siting have already been filed. To bring the project to fruition, a number of ontracts must be negotiated, including contracts for the construction and operation the facility and for the transmission and sale of energy, all of which must be com- eted before the bonds for the plant can be sold. After reviewing both public and ivate ownership options, the county has decided that it prefers to be the owner of e facility.

Once the bonds are sold, the county will notify UOP to proceed with construction. hirty-two months later, the Pinellas County resource recovery facility should be ady for startup. Raw solid waste will then be converted into clean energy and aterials.

Pinellas County is far ahead of most other urban communities with its solid waste ogram. By working together, its citizens and officials are turning their solid waste oblem into a solid solution.

TOPIC III

PLANNING

TOPIC III
PLANNING

ABSTRACTS

WHITMER

Legal and Environmental Issues Surrounding Urban Waste Wood. Materials ha dling to minimize pollution, litter, and complaints, along with careful attention matters of ownership and contracts, must be addressed early in the quest for uti zation of wasted resources. Identification of these considerations serves to impro a project's chance for successful implementation.

LEMPICKI

Coordinating Producers and Consumers of Urban Wood Residues. Sources urban wood waste are both numerous and varied, so finding ways to use this was can be a complex problem. This paper deals with the New Jersey Bureau of Fore Management's program concerning wood waste generated from the seconda processing of wood, locating the manufacturers, estimating their volumes of woo waste, and marketing these materials. The wood waste from secondary wood pro essors is a collectively large source of material often found in urban areas.

PARDO

Urban Waste Wood: The Challenge and the Future. The proceedings of this co ference present a valuable guide to what can be done to convert urban was wood problems into utilization opportunities. The information needs to be com municated as widely as possible. Federal dollars are in short supply for new pr grams, but if these programs are presented as proven ways to save money and lower costs, Congress may be willing to buy what you are selling.

LEGAL AND ENVIRONMENTAL ISSUES SURROUNDING URBAN WASTE WOOD

George L. Whitmer[1]

Abstract.–Materials handling to minimize pollution, litter, and complaints, along with careful attention to matters of ownership and contracts, must be addressed early in the quest for utilization of wasted resources. Identification of these considerations serves to improve a project's chance for successful implementation.

INTRODUCTION

Many aspects of waste wood management are identical to reuse or disposal of unicipal solid waste. In fact, one might envision that processed garbage or baled astepaper might compete with wood waste in the marketplace. The purpose of this resentation is to call attention to several technical and nontechnical considerations hich are shared by waste utilization programs.

Legal and environmental issues cannot easily be separated, for failure to recognize ne aspect would tend to have a great impact on the other. One consideration in parcular, ownership, has the potential to influence a program's financial risk.

Waste wood occurring naturally in a forested area becomes a part of the ecosystem. not only presents no environmental problems other than fire hazard but is utilized y insects and forest animals and recycled through the forest itself. Waste wood ccurring in an urban area presents an entirely different set of circumstances. In most ses, waste cannot be allowed to remain where it occurs. It requires transportation to nother site to be disposed of or to receive further processing. Stumps, limbs, or emolition debris present an operational problem at disposal sites. Most waste wood in ban areas is not the result of natural occurrences but results from land clearing, conruction and demolition, and other activities.

Nature provides a solution for waste wood in the natural environment. It is not an stant solution, but we cannot argue with the results; however, once we alter natural ocesses, it is then up to us to provide solutions for the problems we create.

Waste wood presents a handling problem at any land disposal site. In Georgia, the nvironmental Protection Division (EPD) recognizes two types of approved disposal tes: the sanitary landfill for putrescible (rapidly decomposable) waste, which requires ily cover, and the landfill for nonputrescible (demolition debris, wood waste, etc.) aste, which requires monthly cover. Waste wood normally goes to landfills since it es not decompose rapidly. It presents a handling problem in either type of site ough. Much of it will not compact (tree stumps, logs) and presents a hazard to the uipment operator when mixed with other refuse. A large stump or log is capable of setting a piece of landfill equipment. This type of material also takes up valuable

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space in the landfill because it does not compact well. More cover material is requir to cover logs, stumps, and limbs because the air spaces around them must be fille With the rising cost of land and suitable cover material, these important factors w become even more critical.

Site supervisors have the authority under State law to refuse any waste at a s where acceptance of the material might cause a problem. This stipulation is for t purpose of protecting site operators from hazardous materials. It may also be app cable to waste wood, especially logs, if the supervisor feels that his site is filling up t rapidly or that the wood might constitute an operational problem or be hazardous his personnel or equipment.

It becomes clear that, while protecting the site operator from hazards and preventi overutilization of site space, waste wood that is refused admittance to a site contin to be a disposal problem.

Control over the burning of waste wood is the responsibility of the Air Protecti Branch of the EPD, along with local fire and forestry officials. Permits may be issue under certain circumstances, for existing conical (teepee) burners, land-clearing debr and tree and limb debris resulting from ice or wind storms. In many cases, permits f the burning of land-clearing and storm debris are a local option. However, in count with a population greater than 65,000, burning of land-clearing and storm debris prohibited unless adequate disposal facilities are not reasonably available. Burning permitted in this case, except that no open burning of more than 100 cubic yards p day of land-clearing debris is permitted unless the person performing the burning h first given 2 days' notice of the time and place of the burning to the Director, EP

Air curtain destructors may be permitted for burning of brush and small lim This practice has in some cases led to air pollution problems due to burning of una thorized waste.

ENVIRONMENTAL CONSIDERATIONS

The air in urban areas already contains high quantities of air pollution fr vehicle emissions, industry, and coal-fired boilers. Burning of waste wood adds unn essarily to the already overburdened air in major urban areas and has led to the tig ening of restrictions placed on obtaining a permit for open burning of land-clear and storm debris. Accidental burning of waste wood through acts of nature or carele ness also contributes heavily to the urban air pollution problem. Accidental burni or deliberately set illegal waste wood fires may become a problem following a wind ice storm. Variances of open burning restrictions may be issued by regulatory agenci

Waste wood also has the potential for causing water pollution. This water pol tion may take the form of floating or partially submerged debris in rivers, streams, a lakes. In this form, it poses a hazard to persons skiing, swimming, or fishing in recr tional areas. Water pollution may also take the form of tannic acid leaching in bodies of water from certain types of waste wood. Tannic acid may not be an envir mental problem as it is a natural phenomenon in forested areas; however, tannic a would be a problem if leaching from a tremendous amount of wood waste were occur in a small body of water. Also, as tannic acid can cause darkening of water

may have a negative impact, esthetically, on bodies of water used for recreational purposes.

With the increased cost of natural gas and fossil fuels, wood is becoming an attractive alternative. Wood chips are being used by many industries as boiler fuel to generate process steam. Any industry switching from natural gas or fossil fuels to wood chips or a combination of fossil fuels and wood chips must advise the State Air Protection Branch of the change. Very strict emission controls are required; it is possible that the emission control equipment may have to be altered, or the permit for operation of the boiler may have to be amended. A significant increase in the amounts of fly ash, sulfur dioxide, other particulates, or smoke opacity would require a change in the emission control equipment.

The pulp and paper industry is utilizing much wood waste as fuel. One particleboard company in south Georgia utilizes sander dust as fuel, creating an ash which must be disposed of. Sander dust used in the boilers creates an ash slag; the boilers are blown out four times a day, and there is one day a week for boiler cleaning. During this day, a chemical is added to the boiler walls, hardening the slag so that it may be chipped off. In these sander-dust burners, soft slag puddles at the bottom; all of the slag and ash is presently landfilled.

Another company using a hogged fuel boiler had its ash analyzed for nutrient content. The result was that it did not contain high enough percentages of minerals to offset the hauling expense to a fertilizer company. Recovery of the ash material from this plant would probably be economically feasible if a fertilizer plant were located close by. This plant landfills its ash at the present time.

An Atlanta company that buys fly ash for use in fertilizer and cement purchases the ash from coal but none from wood; the reason for this is that coal fly ash is generally consistent, while that from wood burning is extremely variable. Wood ash varies from source to source, depending on equipment, mixture of fuels, type of supplemental fuels, geographic location, mixture of softwoods and hardwoods, handling procedure, and types of environmental controls used. The company, however, is very interested in the utilization of wood ash and is presently doing research on it.

If large quantities of wood chips, bark, or sawdust are stored outside, certain problems could arise. As mentioned earlier, the leaching of water through this material could cause tannic acid to enter the groundwater and, ultimately, nearby ponds or streams. The storage area could be considered an eyesore by nearby residents who might complain to local officials. Zoning regulations and local nuisance ordinances should be researched beforehand in order that problems of this nature can be avoided.

The major environmental consideration in the transportation of waste wood is litter. The Georgia solid waste law does not specifically require that trucks be covered, but it does require that vehicles be loaded and moved in such a manner that contents will not fall or spill, and it states that vehicles be covered "when necessary" to prevent blowing of material from the vehicle.

LEGAL CONSIDERATIONS

RCRA and the Georgia Solid Waste Management Act do not specifically address the ownership of waste. Waste handling is a local governmental trust in most cases, and

ordinances establishing ownership of waste are generally passed by the city or coun Normally, this will not affect waste wood if it is a material of no fuel value and merely a disposal problem; however, when this waste material becomes a commodity has a monetary value then the legal problem of ownership comes into focus. Comm nities that have instituted curbside newspaper, glass, and aluminum can recycling p grams have had to deal with this problem. Residents would place their garbage curbside for pickup and disposal; at the same time, they would place bundled nev papers, bagged aluminum cans, and glass at the curbside for pickup and placement separate compartments of the garbage truck or in separate trucks for recycling. Pro lems developed when scavengers would precede the garbage truck and pick up t recyclables for sale themselves. Local ordinances had to be passed providing th anything placed at the curbside by the resident was the property of the city.

If a city were selling its waste wood to a mill for use as fuel in its boilers, t wood would then be a commodity. An ordinance would be needed to prevent lo entrepreneurs from collecting and selling the waste wood fuel themselves and th preventing the city from collecting the revenues generated by it.

Military installations sell their waste wood through their Defense Property Dispo Offices. The military considers all waste as government property and has comple ownership of it. Waste wood--wooden crates and boxes, pallets, land-clearing deb demolition and construction debris is sold by the lot on a competitive bid or by t truckload by retail sale. All waste wood has to be paid for before it leaves the milita installation.

In selecting a market for and obtaining a contract to buy or sell waste wood number of elements must be taken into consideration. Most city and county gove ments in Georgia do not allow for contracting beyond a 1-year limit or beyon current administration. This, of course, has made it almost impossible for cities a counties to contract with recycling companies to take scrap material. Many scr companies would have to make an investment in the form of collection, transpor tion, or processing equipment to enter into such an agreement and would not interested in less than a 5-year contract. Exceptions are companies that already recy such materials as scrap metal, newspaper, corrugated board, and glass. They wo require no additional investment to enter short-term contracts. Contracting for a type of waste to be used as a fuel generally requires extensive alteration or constr tion of boilers and conveying equipment and would require a long-term contract.

Subtitle D of RCRA, under requirements for approval of state solid waste pla requires all state plans to provide that local governments can no longer be prohibit from entering into long-term contracts for the supply of solid waste to resource rec ery facilities. This provision would pertain to wood waste which is to be used as a fu

In any contract, provisions should be made for the amounts of allowable conta nants in waste materials. There are strict requirements on contaminants and differe grades of scrap metal and waste paper; waste wood types also have this problem, anyone buying bark for use as fuel can attest. Sand is a major and unavoidable c taminant in shipments of bark; there should be an allowable level which, if exceed would cause a shipment to be rejected. It is amazing how much scrap metal and ot unwanted material tends to turn up in bark shipments.

Contracts should state insurance limits and which party is liable if damage to equipment occurs from contaminated shipments. Metal in a shipment of bark could cause damage to shredding equipment, or bark containing too much moisture might cause boiler corrosion. Liability insurance for personal injuries should be stated in a contract.

Method of payment should also be clearly stated. Military installations require payment for any scrap before it leaves the installation. Other industries are allowed to transport material to their plant, where it is weighed, and payment is then issued. Some contractors buying ferrous metals or aluminum are allowed to transport mixed loads of scrap to their plant, run it through a magnetic separator, and pay according to the amounts of ferrous and nonferrous materials delivered. Payment should be specified as to load, ton, or cubic yard.

A contract should specify minimum and maximum volumes, particularly if the waste material is to be used as a fuel. The industry buying the fuel has a minimum volume that can be utilized in order to maintain operations. The contractor's failure to deliver the minimum volume could jeopardize plant operation. There may also be a problem of receiving too much fuel at the industry if adequate storage area does not exist.

Provisions should be made in the contract for downtime on the part of the fuel user. Boilers and burners will have scheduled downtime for maintenance. During this time, the contractor will still be generating waste wood fuel, and the contract should stipulate where the fuel will go during these downtimes. The same is true for unscheduled maintenance or repair. Many plants have built-in redundancy so that they can remain operating during unscheduled shutdown of the main boiler.

If the ash cannot be utilized, contractual arrangements must be made to dispose of it. If the ash can be used in fertilizer or cement, then additional contracts will be needed between the generator and the buyer; these contracts should specify minimum and maximum volume, type of payment, number and type of contaminants allowed, liability and insurance. The U.S. EPA is currently writing guidelines on the use and disposal of ash; these guidelines also will have to be considered.

SOCIAL AND POLITICAL ASPECTS

Finally, there are certain social and political aspects that must be taken into consideration with respect to waste wood or any other waste.

Local governments have the authority to issue business licenses and to control zoning laws. Any industry changing from one type of fuel to a mixture of that fuel and waste wood (or any other type of waste material) may encounter some opposition from the local zoning board. Also, an industry wanting to locate in an industrial park and burn a waste for fuel may find it more difficult to get zoning approval or a business license.

Whenever waste material is hauled, whether for fuel, recycling, or disposal, there are going to be complaints. Care should be taken to provide that trucks are properly covered to prevent littering. If possible, trucks should be routed to avoid use of residential streets, which will help prevent complaints about noise, dust, damage to

streets, and danger to children. If citizens feel that a facility is emitting too heavy smoke plume, it, as well as governmental regulatory agencies, will get complaint Citizens may also complain if they think water leaching through the waste material getting into nearby water.

A tremendous amount of waste wood occurs from ice storms, hurricanes, an tornadoes. We have already discussed what this extra volume does to the capacity an operation of disposal sites. Some contingency methods should be available to handl this extra waste wood. Limb and tree shredders and chippers are good methods c dealing with this situation. The resulting shredded material may then be used as con post or decorative mulch.

The subject of public relations has been left for last but not because it is lea important. It is imperative that any new procedure be preceded by an extensive publi relations campaign. If a facility is planning a switch from a conventional fuel to burn ing waste wood or any other waste, the citizens should know why. They should b told that it will conserve natural resources, that emissions will continue to meet env ronmental standards, that it will contribute to the longevity of their disposal sites, an that the operation will be clean. A properly informed public will be more apt to we come the facility as a good neighbor. In fact, good public relations–backed up with good operation–may be a facility's most valuable asset.

COORDINATING PRODUCERS AND CONSUMERS OF URBAN WOOD RESIDUES

Edward A. Lempicki[1]

Abstract.–Sources of urban wood waste are both numerous and varied, so finding ways to use this waste can be a complex problem. This paper deals with the New Jersey Bureau of Forest Management's program concerning wood waste generated from the secondary processing of wood, locating the manufacturers, estimating their volumes of wood waste, and marketing these materials. The wood waste from secondary wood processors is a collectively large source of material often found in urban areas.

LOCATING MANUFACTURERS

Companies that use lumber to manufacture wood products often locate in or near urban areas because they are near a large labor supply, are accessible for receiving and shipping materials, and are near markets for their products. Consequently, the secondary processors of wood are concentrated, as are their wood wastes.

To locate and identify these wastes, one must first locate the manufacturers. If no directories of these processors are available, one must be compiled. In most states, the sources of information for such a directory include the Lumbermans National Redbook Service, Dun and Bradstreet listings, and state industrial directories.

A questionnaire can be used to update listings and gather more detailed information. It might include requests for information on the type of raw material used (such as lumber, bolts, plywood), species of wood and amount of wood used annually, products manufactured, estimated amount of wood residue and the percentage used at the plant, and the difficulty of disposing of wood residues.

The New Jersey Bureau of Forest Management constructed such a questionnaire and mailed them to woodworking firms throughout the State (fig. 1). According to the Bureau's survey, there are approximately 1,500 wood-product-manufacturing firms in New Jersey. The responses were organized into product categories, and the location of each company was pinpointed on a State map to give an overall view of area workload. It showed a great industry concentration in the highly populated northeastern section of the State and other clusters around smaller urbanized areas of the State. A direct relationship between population density and location of secondary wood-processing companies was evident. With this information gathered, companies were contacted concerning materials generated as waste from product manufacturers.

ESTIMATING RESIDUE VOLUMES

Residues from the secondary manufacture of wood products fell into two broad categories: dimensional waste such as rippings, cutoffs and rejects; and fine material such as sawdust, shavings, and chips.

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Company Name: ____________________ Address: ____________________
Person to Contact: ____________________ Phone: ____________________

1. Please note the product(s) made (from wood):
____________________ ____________________
____________________ ____________________

2. What form of wood raw materials do you use? Please check.

____ Blanks	____ Precut or Dimension Stock	____ Post
____ Blocks, Cants or Flitches	____ Lumber	____ Roundwood
____ Composition Board	____ Moulding	____ Veneer
____ Fiberboard	____ Piling	____ Other
____ Hardboard	____ Plywood	(Please specify)
____ Particleboard	____ Poles	____________

3. Approximately what quantity of the following species do you use? Please indicate by pe centage.

____ Ash	____ Soft Maple	____ Balsam Fir
____ Basswood	____ Sycamore	____ Western Fir
____ Beechwood	____ Red Oak	____ Eastern Hemlock
____ Birch	____ White Oak	____ Southern Pine
____ Cedar	____ Walnut	____ Western Pine
____ Cherry	____ Yellow-Poplar	____ White Pine
____ Hickory	____ Mixed Hardwoods	____ Eastern Spruce
____ Hard Maple	____ Tropical Woods	____ Mixed Softwoods

Other (please specify) ____________________

4. Please indicate your annual requirement of wood, according to your method of measuremer
Board Feet ____________ Cords ____________
Square Feet ____________ Tons ____________
Linear Feet ____________ Other ____________

5. What residues are produced in your operation(s) that are currently going unused? Plea check.

____ Bark	____ Cores	____ Sawdust	____ Rippings, Cutof
____ Chips	____ Excelsior	____ Shavings	____ Wood Flour

____ Other (Please specify) ____________________

6. Annual Wood Residue Volume and Method of Disposal.
Wood Fines (sawdust, shavings, etc.) ______cubic yards or tons
Dimensional Waste (ripping, cutoffs, etc.) ____cubic yards or tons
Method of Disposal ____________________

7. How many personnel are in your firm? ____________________

8. Please check, if you desire a copy of this directory____________________

9. Comments:

Figure 1.—Secondary wood-using industry survey.

The amount of waste produced depends on the product being manufactured, th volume and quality of raw material used, and the efficiency of production. The rang in amount of waste can be wide from less than 5 percent to more than 50 percent c the raw material. In the manufacture of floor trusses, the waste might be about 5 pe cent of the volume of raw material but 50 percent for wood shoe heels.

Collectively, the industry was having great difficulty with these waste material: Most of it was being contracted for landfill disposal at substantial cost to the produce

An estimated 20 million cubic feet of this material were disposed of in this manner annually. This is not only a costly burden but also a tremendous waste of a resource.

Specific information must be obtained on residue type, production, and availability. The only accurate way to obtain volume information is by measurement, but most companies know the volume of residues produced over a period of time in general terms by a hopper, container, or truckload. Normally, wood fines and dimensional waste from a particular producer must be categorized separately.

In the case of wood fines, the important factors concerning marketability are species, grade, particle size, moisture content, quantity, and storage capacity. Samples of the material should be collected and specifically identified in these terms for future reference. Dimensional waste, rippings, cutoffs and product rejects are more difficult to define accurately. Quite often a range of dimensional material is normally generated. Basically, this material may be grouped into broad categories with average sizes noted. Often only a portion can be marketed, so separate information must be obtained for each category. Samples are required since this material is often difficult to describe accurately.

MARKETS FOR RESIDUES

A particular residue must not only fit a specific use but must also be produced in sufficient quantity to allow marketing on an economically sound basis. Hence, available markets must be investigated as thoroughly as the producers; information is needed on material specifications, volume requirements, and the buyer's shipping, receiving, and storing facilities.

While markets for residues are as numerous and varied as the producers, the major markets for dimensional waste include the shipping industry (for storing and bracing), other secondary processors, landscapers and nurserymen (for stakes), and the residue dealers and companies that use the wood fines in a variety of products.

There are wood-residue companies located in New Jersey that collect, store, refine, package, and deliver sawdust, shavings, chips, and other forms of wood residues to a multitude of markets. Sawdust, for instance, has a variety of applications; sweeping, absorbent and cleaning compounds, animal bedding, metal polishing, and wood fines for plastic and rubber processing are just a few uses. The average residue dealer in New Jersey handles about 8,000 tons of wood fines per year. On a cubic-foot basis, this equals roughly 1.5 million cubic feet of material, or enough fines to fill 700 large tractor-trailers. The Bureau has been working with these residue dealers and other demand sources and has had substantial success in diverting material from landfills to more productive uses.

Utilization possibilities exist not only for wood fines but also for rippings, cutoffs, and product rejects. This kind of material is the common result of sizing and shaping lumber for product manufacture. Through our visits, we found that one company's dimensional residues may well be acceptable as another manufacturer's raw material. Companies producing the same products generate residue types that are essentially the same; however, those manufacturing entirely different products tend to create utilization possibilities. Experience has shown that most often a particular company's entire dimensional residue production cannot be recycled to another manufacturer for reuse.

Usually, a portion of this material has potential—a particular cutoff-size range or al rippings larger than a specified minimum width. The important point is, however, tha data must be obtained for the entire range of dimensional residues generated.

SUMMARY

The wood-using industry has accepted the Wood Residue Utilization Program anc is cooperating well. The residues generated from product production come in many different forms and can really be thought of as a resource, every bit as renewable a trees themselves.

The problems and pitfalls of recycling wood residues are many. Raw materia sources must first be located; locating must be followed by an on-site survey, some thing which requires a great deal of time and effort. Actual samples of material fron specific sources are needed since use is usually rather specific, and wood residues especially those generated by wood-product manufacturers, are quite variable anc difficult to describe accurately. Also, the material seems more attractive to a potentia buyer if it can be seen and possibly tried for use.

Experience has shown that waste wood must really sell itself. One must first have something that a potential buyer can use. Not only must it be acceptable for a specifi use or product, but it must also be available at the right price. Further, waste wooc involves a certain cost for storage, handling, and transport. Economics is ultimately th deciding factor and most often the real incentive to both residue producer and user There is a wide range of uses for wood residues both inside and outside of the wood products industry, and most of this material need not be a burden.

URBAN WASTE WOOD: THE CHALLENGE AND THE FUTURE

Richard Pardo[1]

Abstract.–The Proceedings of this Conference present a valuable guide to what can be done to convert urban waste wood problems into utilization opportunities. The information needs to be communicated as widely as possible. Federal dollars are in short supply for new programs, but if these programs are presented as proven ways to save money and to lower costs, Congress may be willing to buy what you are selling.

This Conference has been a real learning experience for me, and I want to commend ie people who put the meeting together and each of the speakers for a job well done. he Proceedings of the meeting will be a gold mine of valuable information and ideas an area that so far has gone almost unnoticed.

Let me begin with a few words about the American Forestry Association for those you who may not be familiar with AFA. We are neither a trade association nor a ofessional society but are a citizen conservation organization. Membership is open to yone. We are perhaps best known for our monthly magazine "American Forests." ur primary role is conservation education: informing the public about the broad ectrum of forest-land management opportunities and issues. We are communicators AFA, which is one reason why I am excited by what I have heard here at this conrence. The information presented here is specific, practical, and tremendously useful. ow it needs to be communicated.

Are we really talking about problems, or are we also talking about opportunities? ne man's problem can be another's opportunity. Perhaps what we really have is a oblem of communication–communication between the person with the waste wood d the one for whom that wood may be an opportunity.

With that thought in mind I want to begin by taking a quick look back at the last days to see whether our speakers were talking about problems, or opportunities, or out turning problems into opportunities.

Ken Cordell began by setting the stage with an overview of the urban waste wood uation.

Steve Dennison followed with a discussion of one solution to the communications oblem: Fibrest, a computerized inventory program. Certainly this is a key element in idging the gap from problem to opportunity. He noted that so far we have failed to ply either modern management or modern technology to the disposal of urban ood waste.

Tommy Loggins was next with a description of another part of the inventory ocess: the landfill survey made by the Georgia Forestry Commission in Atlanta,

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which clearly showed that a large volume of usable wood was being discarded. He again, was an effort to identify a problem which could be turned into opportunity.

George Whitmer was next, with a discussion of the legal problems involved waste wood disposal and utilization. I was particularly glad that he mentioned t value of public relations in these kinds of programs. It is important to let the pub know what you are doing. This aspect is often overlooked unless the public is son how directly involved in the program.

Millard Davis discussed the difficult problem of source separation. He warned n to tie your waste wood program to other recycling efforts such as waste paper aluminum. If those fail, for any reason, your waste wood goes down with them.

Dave DeVoto spoke next. He described the ups and downs, the successes and fa ures, in trying to deal with a massive problem of urban waste wood from Dutch e disease in the Minneapolis-St. Paul area. There was no question which this was; it w a problem that needed a solution, and this is a case-history worth documenting.

Dave Walker then talked about the other side of this same coin: how at Georg Tech they were able to set up a program to use wood resulting from a natural disas and save the school some $10,000 by turning the problem of wasted trees into usal mulch.

Ed Lempicki followed with a description of still another opportunity from wa wood, describing how tree contractor Sam Willard saved disposal costs and turn expense into income by operating his own specialty sawmill to convert waste urb trees into specialty wood products. As the saying goes: if you get a lemon, ma lemonade.

The next speaker, Jim Commins, described the urban demolition and constructi wood survey conducted by his company and the way in which they were using the woods for landfill and productive use. He said that there is a market out there beca the supply is almost everywhere, costs of competitive materials are rising, solid wa laws are getting tougher, and attitudes of municipal officials are changing for the bett

Jay Lowery focused on the fuelwood situation, with an example of how t disposal problem was converted into a utilization opportunity in Atlanta with t institution of public fuelwood dumps. And he predicted that more of this material w be converted into salable chips in the future.

Alex Cobb described one method of fuel preparation, the use of a hog. He ob ously feels that urban waste wood is an opportunity since he concluded that he is the right business at the right time. He also provided us with some examples of t various products and uses for hogged waste wood.

Jack Howard spoke next, describing the functions of a broker in the process turning one man's waste product into another's raw material. Here was the voice experience. He described several ongoing activities in which he is engaged, and he out a step-by-step procedure for marketing wood residues.

John Sturos described some of the research projects being carried out at Michig Tech to improve utilization technology, including a detailed slide and film descripti of an innovative vacuum system to separate usable materials from whole-tree chips.

Jim McMinn took a close look at the wood energy picture and suggested that the problem may be not how we dispose of urban waste wood but rather how we can get more of it. He pointed out that not every situation is right for converting waste wood to wood energy but that in some areas the potential is great and growing.

Gloria Mills presented a fascinating description of how Pinellas County, Florida, will be creating energy from municipal waste, with a highly sophisticated and technologically advanced waste conversion plant.

Ed Lempicki took the podium for a second time to describe how he and his New Jersey colleagues are serving the brokerage function in their State by bringing waste products together with waste users to turn problems into opportunities.

Which brings me back to my starting point: do we have a problem, or are these really opportunities that need better communications to be realized?

Frankly, I would not look to Washington at this time to finance the kinds of things that we are talking about here. The federal budget is tight, new programs are not being considered because of inflation and, as the previous speaker said, few people in Washington know there is a problem of urban waste wood.

My advice to you is not to go to Washington and say that you have a waste wood problem. Instead, go to Washington and tell your Congressmen how *you* can help *them*. You have the examples of what has been done and what can be done. You have a solution, not another problem.

I have a feeling that if we can get the word out on the potential savings or profits that you have shown are possible, the people in Washington may begin to pay attention.

I would encourage you to be evangelists in the cause of turning urban waste wood problems into opportunities. In other words, keep on doing what you have been doing. There must be hundreds of municipal foresters, solid waste managers, politicians, tree companies, wood users, and homeowners who would be delighted to know that things can be done, that the technology exists, and that although you may not make a profit, you certainly may save a dollar.

We will do our best at AFA to help you spread the word.

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Southeastern Forest Experiment Station and others

1979. Urban waste wood utilization: proceedings of a conference on alternatives to urban waste wood disposal, March 26-28, 1979. U.S. Dep. Agric. For.Serv., Gen. Tech. Rep. SE-16, 127 p. Southeast. For. Exp. Stn., Asheville, N. C.

Included in the Conference Proceedings are five papers on the resource situation, nine papers on possibilities for utilization, and three papers on planning.

Keywords: Wood residues, wood manufacturing, chipping.

NATIONAL FOREST SYSTEM
COOPERATIVE FORESTRY
FOREST SERVICE
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DEPARTMENT OF AGRICULTURE
FORESTRY RESEARCH

USDA Forest Service Southeastern Forest Experiment Station
General Technical Report nos. 17 & 18 are missing from our
collection and can not be obtained.

United States
Department of
Agriculture

Southeastern Forest
Experiment Station

Forest Service
General Technical Report
SE-19

RECAL:

A Computer Program for Selecting Sample Days for Recreation Use Estimation

by D. L. Erickson, C. J. Liu, H. K. Cordell, and W. L. Chen

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RECAL: A Computer Program for Selecting Sample Days for Recreation Use Estimation

by

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RECAL:
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ABSTRACT.--Recreation Calendar (RECAL) is a computer program in PL/I for drawing a sample of days for estimating recreation use. With RECAL, a sampling period of any length may be chosen; simple random, stratified random, and factorial designs can be accommodated. The program randomly allocates days to strata and locations.

Federal and State land management agencies must regularly and reliably estimate visitor use of recreation areas under their control. Only in this way can funds be appropriately allocated among recreation areas and needs for expansion discovered. Various methods of data collection and analysis are employed, depending upon the sorts of information needed, but most methods require observation on a certain number of randomly selected days. This report describes a computer program for random selection of sampling days.

The program, called RECAL, is written in PL/I. The Appendix of this report contains a complete listing of RECAL. This program is designed to accommodate simple random sampling in which all days are treated alike, stratified random sampling in which high use days and low use days are placed in different strata, or factorial designs. The program can produce:

1. A Gregorian calendar for the sampling period desired.[2/]

2. A schedule of sample days by calendar day, day of the week, and site location.

3. The number and percentage of sample days allocated to each location and stratum.

Program Input

To use RECAL, two decisions must be made--the length of sampling period and the sampling design. The sampling period can be as long or short as desired, but it must be continuous.

[2/] The construction of the Gregorian calendar is based on formulas given by H. E. Licks, 1917, Recreations in mathematics. D. Van Nostrand Co., New York, 155 p.

In selecting the sampling design, strata and sampling intensity must be specified. Recreation use in RECAL may be conveniently divided into two strata: stratum A (heavy use days) and stratum B (light use days). A simple random sampling will be performed within each stratum according to the sampling intensity specified. A particular day chosen for sampling will then be randomly allocated to a sampling location.

Control Cards

One control card and one or more name cards are required. Each data field should be separated by one or more blank columns. Table 1 shows an example of the input cards required.

Field Number One is named START. It specifies the beginning of the sampling period by up to two-digit codings for month and day of the month, and a four-digit coding for the year, in that order. Each is separated from the others by either a comma or a blank.

Field Number Two, named END, specifies the ending date of the sampling period. It is coded the same as Field Number One.

Field Number Three, named LOC, specifies the total number of sampling locations.

Field Number Four, named LEVEL, defines the stratum or the level of use for the particular day of the week. In the program, the first day of the week is designated as Sunday and the last day as Saturday. Users should code the digit 0 to designate a heavy use day and the digit 1 a light use day. Days of the week are separated by commas and are coded in order. When simple random sampling design is desired, all days should be coded by 0's.

Field Number Five, named MODEL, specifies the particular sampling design to be used. Code 1 for simple random sampling, 2 for stratified random sampling, and 3 for factorial design.

Field Number Six is named INTEN. The coding of this field depends on the particular sampling design:

1. Simple random sampling--To indicate the sampling intensity, the user may choose to use either the sample size or the percentage of the population to be sampled. For example, a sampling intensity of 20 percent would be coded in INTEN as .20, while the sample size will be coded as an integer.

2. Stratified random sampling--Coding is the same as simple random sampling.

3. Factorial design--INTEN is coded by the total number of sample days as a negative integer variable (*e.g.*, -20). This number should be divisable by the number of sample locations since an equal number of observations is assumed for the factorial design.

Field Number Seven is named CALDR. If specified, the program will produce a Gregorian calendar of the years covering the sampling period. Code 1 if yes, 0 if no.

Field Number Eight is called NAME. If specified, the program will produce a listing of the names of the sampling locations. Code 1 if yes and 0 if no.

Field Number Nine is called HEAVY. This field allows the user to designate other known heavy use days (*e.g.*, national holidays, local festivals) not covered by Field Number Four. If no heavy use days occur during the specified sampling period, the user should code the field 0 (zero).

Name Cards

For inputing names, location names must be coded in quotation marks and separated by blanks (table 1). The name cards should follow the control card.

Heavy Use Cards

The specific dates of expected heavy use days should be coded on Heavy Use Cards that follow the Name Card in the input stream (table 1). Each expected heavy use day is coded by either a one- or two-digit number for the month and for the day of the month, and a four-digit number for the year, in that order. Two or more heavy use days are separated by blanks.

Program Output

The program uses a random number generator to select the sample days, and randomly allocates these days to different locations. An example of the RECAL program output is shown in table 2.

The program first prints out a summary of the sampling plan, which verifies the input specified on the control card. In this example, the user has chosen a stratified random sampling with a period starting on November 29, 1979, and ending on January 30, 1980. Stratum A defines the heavy use days and stratum B defines the light use days. The number of available sampling days for each stratum is printed and each stratum will be sampled at an intensity of 20 percent. There are six sampling locations. Based on the number of available days in each stratum, 4 heavy use days and 9 light use days were chosen. Each of these days were randomly allocated to one of the six locations.

The program then prints out a sampling schedule. In the sampling schedule, the sample days are listed sequentially by calendar date, day of the week, and location. Optionally, the name of the location can be printed.

Following the sampling schedule, a printout of the number and percentage of sample days allocated to the specified locations and to each stratum is given.

Table 1.--An example of input cards for RECAL

Control Card Format

Field Number	Field Name	Code	Explanation of Code
1	START	11,29,1979	Starting date is Nov. 29, 1979
2	END	1,30,1980	Ending date is Jan. 30, 1980
3	LOC	6	Six sampling locations
4	LEVEL	0,1,1,1,1,1,0	Heavy use days are Sun. and Sat. Light use days are Mon., Tues., Wed., Thurs., and Fri.
5	MODEL	2	Stratified random sampling
6	INTEN	.20	Sampling intensity is 20%
7	CALDR	0	No calendar printed
8	NAME	1	Print location names
9	HEAVY	1	One heavy use day specified

Control Card Image

```
11,29,1979    1,30,1980    6    0,1,1,1,1,1,0    2    .20    0    1    1
```

Name Card Images

```
'Road 23'        'Pine Ridge'       'Tunnel Ridge Road'       'CCC Camp'
                     'Koomer Ridge'        'Nada Tunnel'
```

Heavy Use Card Image

```
12,25,1979
```

Table 2.--An example of RECAL output

```
*******************************
*   SUMMARY OF SAMPLING PLAN   *
* FOR STRATIFIED RANDOM SAMPLE *
*******************************

  SAMPLING PERIOD:  NOV 29 1979-JAN 30 1980
  DEFINITION OF STRATA
            STRATUM A:  SUN SAT
            STRATUM B:  MON TUE WED THU FRI
            SAMPLING INTENSITY:  20.00%
            NO. OF DAYS IN STRATUM A:    19
            NO. OF DAYS IN STRATUM B:    44
            NO. OF SAMPLING LOCATIONS:  6

***************************************************
* SAMPLING SCHEDULE FOR NOV 29 1979 - JAN 30 1980 *
***************************************************
```

DATE	DAY	LOCATION	
NOV 29	THU	4	CCC CAMP
DEC 1	SAT	6	NADA TUNNEL
DEC 6	THU	4	CCC CAMP
DEC 20	THU	2	PINE RIDGE
DEC 22	SAT	5	KOOMER RIDGE
DEC 24	MON	6	NADA TUNNEL
JAN 2	WED	5	KOOMER RIDGE
JAN 4	FRI	6	NADA TUNNEL
JAN 10	THU	1	ROAD 23
JAN 17	THU	1	ROAD 23
JAN 20	SUN	1	ROAD 23
JAN 26	SAT	3	TUNNEL RIDGE ROAD
JAN 29	TUE	6	NADA TUNNEL

```
***********************************
* SAMPLING ALLOCATION BY LOCATION *
***********************************
```

LOCATION	SAMPLE SIZE	PERCENTAGE
1	3	23.08%
2	1	7.69%
3	1	7.69%
4	2	15.38%
5	2	15.38%
6	4	30.77%

```
**********************************
* SAMPLING ALLOCATION BY STRATUM *
**********************************
```

STRATUM	SAMPLE SIZE	PERCENTAGE
A	4	6.35%
B	9	14.29%

APPENDIX
Listing of Source Deck

```
ISAMPLE:PROCEDURE OPTIONS(MAIN);
DCL NAMES(ISITE) CHAR(20) CONTROLLED;
DCL DAYS(HVY,3) FIXED BIN CONTROLLED;
DCL (RAN,RATE,RAM) FLOAT BIN(31);
DCL SEED FLOAT(16);
DCL (START(3),END(3),TEST,T,ISITE,DET(7),SDAY(2),OPTION1,OPTION2,
    STOP(4),M,N,K,CURRENT_DAY,NN,TOTAL,IDAY(2),OPTION3,HVY,FLAG,
   I,J,CURRENT_MO,CURRENT_YR WK) FIXED BIN (31);
DCL  MO(12) FIXED BIN(31) INIT(31,28,31,30,31,30,31,31,30,31,30,31);
DCL  FWD(12) FIXED BIN(31) INIT(365,334,306,275,245,214
     ,184,153,122,92,61,31);
DCL  BWD(12) FIXED BIN(31) INIT(0,31,59,90,120,151,181,
    212,243,273,304,334);
DCL DAY(7) CHARACTER(3) INIT ('SUN','MON','TUE','WED','THU','FRI',
                              'SAT');
DCL MONTH(12) CHARACTER(3) INIT ('JAN','FEB','MAR','APR','MAY','JUN',
                                 'JUL','AUG','SEP','OCT','NOV','DEC');
DCL (WEEKEND,WEEKDAY)FLOAT(6);
DCL  (FIXED,MOD,SUM,PROD,ABS) BUILTIN;
DCL   LEAP ENTRY(FIXED BIN(31),FIXED BIN(31));
DCL  WEEK ENTRY(FIXED BIN(31),FIXED BIN(31),FIXED BIN(31));
DCL  RANDM ENTRY(FLOAT(16),FIXED BIN(31),FLOAT BIN(31));
GET LIST(START,END,ISITE,DET,OPTION3,RATE,OPTION1,OPTION2,HVY);
IF HVY > 0 THEN DO; ALLOCATE DAYS;
                    GET SKIP LIST(DAYS);
                    END;
ALLOCATE NAMES;
IF OPTION2=1 THEN DO;
                     GET SKIP LIST(NAMES);
                     END;
          ELSE NAMES='';
IF ((START(3)>END(3))|(START(3)=END(3)&START(1)>END(1)) |
   (START(3)=END(3)&START(1)=END(1)&START(2)>END(2)))
           THEN DO; PUT LIST('STARTING DATE IS GREATER THAN ENDING
                             DATE, JOB ABORTED'); STOP; END;
MO(2)=29; RAM=1.;
IF(START(1)>12 | START(2)>MO(START(1))  |
   END(1)>12 | END(2)>MO(END(1))) THEN
        DO; PUT LIST ('ERROR IN THE DATES SPECIFIED, JOB ABORTED');
            STOP; END;
IF ISITE<1 THEN DO;
            PUT LIST ('NOT ENOUGH LOCATION, JOB ABORTED');
            STOP; END;
IF SUM(DET)>7 THEN DO;
            PUT LIST ('ERROR IN THE LEVEL SPECIFIED, JOB ABORTED');
            STOP; END;
IF OPTION3=1 THEN IF ( SUM(DET)¬=0) THEN DO;
            PUT LIST(' ERROR IN THE LEVEL SPECIFIED; JOB ABORTED');
            STOP; END;
IF (OPTION3=3 & MOD(RATE,ISITE)¬=0) THEN DO;
            PUT LIST(' ERROR IN THE INTENSITY SPECIFIED; JOB ABORTED');
            STOP; END;
IF OPTION1=0 THEN GO TO SA;
PUT  EDIT((100)'*')(PAGE,A);
```

```
DO I=1 TO END(3)-START(3)+1;
 PUT SKIP(10);
 PUT EDIT (START(3)+I-1) (COL(34),F(4));
 DO J=1 TO 4;
  PUT SKIP(3);
  SELECT;
   WHEN(J=1) PUT LIST('        JANUARY                         FEBRUARY',
    '          MARCH');
   WHEN(J=2) PUT LIST('        APRIL                           MAY',
    '          JUNE');
   WHEN(J=3) PUT LIST('        JULY                            AUGUST',
    '          SEPTEMBER');
   WHEN(J=4) PUT LIST('        OCTOBER                         NOVEMBER',
    '          DECEMBER');
 END;
  PUT SKIP LIST(' S  M  T  W  T  F  S      S  M  T  W  T  F  S',
     '     S  M  T  W  T  F  S');
  CALL LEAP(START(3)+I-1,T);
  PUT SKIP;
  DO M=1 TO 3;
   IF M+3*(J-1)>2 THEN CALL WEEK(START(3)+I-1,BWD(M+3*(J-1))+T+1,WK);
                  ELSE CALL WEEK(START(3)+I-1,BWD(M+3*(J-1))+1,WK);
   IF WK=0 THEN WK=WK+7;
   STOP(M)=8-WK;
   DO N=1 TO STOP(M);
   PUT SKIP(0) EDIT(N)(X((M-1)*25+(WK-1)*3+(N-1)*3),F(3)); END;
  END;
  IF T¬=0 THEN MO(2)=29; ELSE MO(2)=28;
  DO K=1 TO 5;
  PUT SKIP;
  DO M=1 TO 3;
   STOP(M)=STOP(M)+7; NN=0;
   IF STOP(M)<MO(M+3*(J-1)) THEN DO; DO N=STOP(M)-6 TO STOP(M);
                          PUT SKIP(0) EDIT(N)(COL(1+(M-1)*25+NN*3)
                                 ,F(3)); NN=NN+1;  END; END;
               ELSE IF STOP(M)-6<=MO(M+3*(J-1))
                    THEN DO; DO N=STOP(M)-6 TO MO(M+3*(J-1));
                         PUT SKIP(0) EDIT(N)(COL(1+(M-1)*25+NN*3)
                                 ,F(3)); NN=NN+1;  END; END;
    END;
   END;
  END;
 END;
SA: MO(2)=28;
TOTAL=(END(3)-START(3)+1)*366;
BEGIN;
 DCL (SAMPLE_DAY(2,TOTAL,7),SITE(ISITE)) FIXED BIN (31);
 IF START(1)<=2 THEN TOTAL=BWD(START(1))+START(2);
             ELSE DO; CALL LEAP(START(3),T);
                      TOTAL=BWD(START(1))+START(2)+T;
                      END;
 CALL WEEK(START(3),TOTAL,WK);
 IF WK=0 THEN WK=WK+7;
 CURRENT_DAY=START(2); CURRENT_MO=START(1); CURRENT_YR=START(3);
```

```
IDAY=1; TOTAL=0; SAMPLE_DAY(*,*,6)=0;
DO WHILE ((CURRENT_YR<END(3)) | ((CURRENT_YR=END(3)) &
         (CURRENT_MO<END(1))) | ((CURRENT_YR=END(3)) &
         (CURRENT_MO=END(1)) & (CURRENT_DAY<=END(2))));
  TOTAL=TOTAL+1;
   FLAG=0;
   IF HVY=0 THEN GO TO NOR;
            ELSE DO;
                 DO I=1 TO HVY;
                 IF CURRENT_YR=DAYS(I,3) & CURRENT_MO=DAYS(I,1)
                    & CURRENT_DAY=DAYS(I,2) THEN DO;
                   FLAG=1;
                  SAMPLE_DAY(1,IDAY(1),1)=CURRENT_MO;
                  SAMPLE_DAY(1,IDAY(1),2)=CURRENT_DAY;
                  SAMPLE_DAY(1,IDAY(1),3)=CURRENT_YR;
                  SAMPLE_DAY(1,IDAY(1),4)=WK;
                  SAMPLE_DAY(1,IDAY(1),7)=TOTAL;
                  IDAY(1)=IDAY(1)+1; WK=WK+1;
                  GO TO NOR;
                  END;
                 END;
                END;
 NOR: IF FLAG¬=1 THEN DO;
   SAMPLE_DAY(DET(WK)+1,IDAY(DET(WK)+1),1)=CURRENT_MO;
   SAMPLE_DAY(DET(WK)+1,IDAY(DET(WK)+1),2)=CURRENT_DAY;
   SAMPLE_DAY(DET(WK)+1,IDAY(DET(WK)+1),3)=CURRENT_YR;
   SAMPLE_DAY(DET(WK)+1,IDAY(DET(WK)+1),4)=WK;
   SAMPLE_DAY(DET(WK)+1,IDAY(DET(WK)+1),7)=TOTAL;
   IDAY(DET(WK)+1)=IDAY(DET(WK)+1)+1; WK=WK+1;
   END;
   IF WK>7 THEN WK=1;
   CALL LEAP(CURRENT_YR,T);
   IF T=1 THEN MO(2)=29;
          ELSE MO(2)=28;
   CURRENT_DAY=CURRENT_DAY+1;
   IF CURRENT_DAY>MO(CURRENT_MO) THEN DO;
                                 CURRENT_DAY=1;
                                 CURRENT_MO=CURRENT_MO+1;
                                 IF CURRENT_MO>12 THEN DO;
                                           CURRENT_MO=1;
                                           CURRENT_YR=CURRENT_YR+1;
                                           END;
                                      END;
 END;
IDAY=IDAY-1; SITE=0;
IF OPTION3=2 THEN DO; IF RATE>1 THEN
                                SDAY=RATE/TOTAL*IDAY+.5;
                                ELSE SDAY=RATE*IDAY+.5;
                                END;
IF OPTION3=1 THEN  DO; IF RATE<1 THEN J=RATE*TOTAL+.5;
                                 ELSE J=RATE;
                                 END;
IF OPTION3=3 THEN SDAY=RATE/2;
IF(SDAY(1)>IDAY(1) | SDAY(2)>IDAY(2)) THEN DO;
```

```
      PUT LIST(' MAXIMUM NO. OF SAMPLE DAYS EXCEEDED, JOB ABORTED');
      STOP;
      END;
 SEED=2*(START(3)*1000+START(2)*100+START(1)*10)+11;
 IF OPTION3=1 THEN DO;
                   SDAY=0;
                   DO I=1 TO J;
               RB: CALL RANDM(SEED,1,RAN);
                   IF RAN>IDAY(1)*RAM/TOTAL THEN N=2; ELSE N=1;
                   CALL RANDM(SEED,1,RAN);
                   K=RAN*IDAY(N)+1;
                   IF SAMPLE_DAY(N,K,6)=1 THEN GO TO RB;
                                          ELSE SAMPLE_DAY(N,K,6)=1;
                              CALL RANDM(SEED,1,RAN);
                              SDAY(N)=SDAY(N)+1;
                              SAMPLE_DAY(N,K,5)=ISITE*RAN+1.;
                                DO M=1 TO ISITE;
                                IF SAMPLE_DAY(N,K,5)=M THEN
                                                SITE(M)=SITE(M)+1;
                                 END;
                   END;
                 END;
                ELSE DO;
 DO I=1 TO 2;
  DO J=1 TO SDAY(I);
RA:CALL RANDM(SEED,1,RAN);
   K=RAN*IDAY(I)+1;
   IF SAMPLE_DAY(I,K,6)=1 THEN GO TO RA; ELSE SAMPLE_DAY(I,K,6)=1;
   IF OPTION3=3 THEN SAMPLE_DAY(I,K,5)=MOD(J+(I-1)*SDAY(1),ISITE)+1;
                ELSE DO;
   CALL RANDM(SEED,1,RAN);
   SAMPLE_DAY(I,K,5)=ISITE*RAN+1;
   END;
   DO M=1 TO ISITE;
    IF SAMPLE_DAY(I,K,5)=M THEN SITE(M)=SITE(M)+1;
   END;
  END;
 END;
 END;
 PUT SKIP EDIT((34)'*')(PAGE,X(14),A);
 PUT SKIP EDIT('*','*')(X(14),A,X(32),A);
 PUT SKIP LIST('                *    SUMMARY OF SAMPLING PLAN    *');
 IF OPTION3=1 THEN
 PUT SKIP LIST('                *    FOR SIMPLE RANDOM SAMPLE    *');
 IF OPTION3=2 THEN
 PUT SKIP LIST('                *  FOR STRATIFIED RANDOM SAMPLE  *');
 IF OPTION3=3 THEN
 PUT SKIP LIST('                *      FOR FACTORIAL DESIGN      *');
 PUT SKIP EDIT('*','*')(X(14),A,X(32),A);
 PUT SKIP EDIT((34)'*')(X(14),A);
 PUT SKIP(5) EDIT('  SAMPLING PERIOD:',MONTH(START(1)),START(2),
                 START(3),'-',MONTH(END(1)),END(2),END(3))
                  (COL(16),A,A(3),F(3),F(5),A,A(3),F(3),F(5));
 PUT SKIP(2) ('                     DEFINTION OF STRATA');
```

```
 PUT SKIP(2) EDIT ('STRATUM A:')(COL(27),A);
 K=0;
 DO I=1 TO 7;
   IF DET(I)=0 THEN DO; PUT EDIT(DAY(I))(COL(38+K*4),A(3));
                        K=K+1;
                        END;
 END;
 PUT SKIP(2) EDIT ('STRATUM B:')(COL(27),A);
 K=0;
 DO I = 1 TO 7;
    IF DET(I)=1 THEN DO; PUT EDIT(DAY(I))(COL(38+K*4),A(3));
                         K=K+1;
                         END;
 END;
 IF RATE>1 THEN
                  PUT SKIP(2) EDIT('  SAMPLING INTENSITY:',
                                 RATE*100./TOTAL,'%')
                                  (COL(25),A,F(6,2),A);
             ELSE
              PUT SKIP(2) EDIT('  SAMPLING INTENSITY:',RATE*100.,'%')
                             (COL(25),A,F(6,2),A);
PUT SKIP(2)EDIT('  NO. OF DAYS IN STRATUM A:',IDAY(1))(COL(25),A,F(5));
PUT SKIP(2)EDIT('  NO. OF DAYS IN STRATUM B:',IDAY(2))(COL(25),A,F(5));
 PUT SKIP(2)EDIT('  NO. OF SAMPLING LOCATIONS:',ISITE)(COL(25),A,F(3));
 PUT PAGE EDIT ((53)'*')(X(14),A);
 PUT SKIP EDIT('*','*')(X(14),A,X(51),A);
 PUT SKIP EDIT('*  SAMPLING SCHEDULE FOR',MONTH(START(1)),START(2),
                 START(3),' - ',MONTH(END(1)),END(2),END(3),'*')
       (COL(15),A,X(1),A(3),F(3),F(5),A,A(3),F(3),F(5),X(2),A);
    PUT SKIP EDIT('*','*')(X(14),A,X(51),A);
    PUT SKIP EDIT((53)'*')(X(14),A);
 IF OPTION2=0 THEN PUT SKIP(5) EDIT('DATE      DAY     LOCATION')
                                  (COL(18),A);
    ELSE PUT SKIP(5)EDIT('DATE      DAY          LOCATION')
                                  (COL(18),A);
PUT SKIP EDIT((45)'-')(X(14),A);
 PUT SKIP(2);
 DO I=1 TO TOTAL;
  DO J=1 TO 2;
    DO K= 1 TO IDAY(J);
       IF SAMPLE_DAY(J,K,7)>I THEN GO TO IJ;
       IF SAMPLE_DAY(J,K,7)=I & SAMPLE_DAY(J,K,6)=1
                                  THEN DO;
                                  PUT SKIP(1);
                                  PUT EDIT(MONTH(SAMPLE_DAY(J,K,1)),
                                         SAMPLE_DAY(J,K,2),
                                         DAY(SAMPLE_DAY(J,K,4)),
                                         SAMPLE_DAY(J,K,5),
                                         NAMES(SAMPLE_DAY(J,K,5)))
                     (COL(16),A(5),F(2),X(5),A(8),F(3),X(3),A(20));
                                  GO TO KK;
                                  END;
     END;
IJ:END;
```

```
 KK:END;
  PUT PAGE EDIT((37)'*')(X(14),A);
  PUT SKIP EDIT('*','*')(X(14),A,X(35),A);
  PUT SKIP LIST('              *  SAMPLING ALLOCATION BY LOCATION  *');
  PUT SKIP EDIT('*','*')(X(14),A,X(35),A);
  PUT SKIP EDIT((37)'*')(X(14),A);
  PUT SKIP(5) EDIT (' LOCATION  SAMPLE SIZE  PERCENTAGE')
                  (COL(14) A);
 PUT SKIP EDIT((36)'-')(X(14),A);
  DO I=1 TO ISITE;
  PUT SKIP(2) EDIT(I,SITE(I),SITE(I)*100.*RAM/SUM(SDAY),'%')
                  (COL(17),F(3),F(12),F(13,2),A);
  END;
  PUT PAGE EDIT ((36)'*')(X(14),A);
  PUT SKIP EDIT ('*','*')(X(14),A,X(34),A);
 PUT SKIP LIST('              *  SAMPLING ALLOCATION BY STRATUM  *');
 PUT SKIP EDIT('*','*')(X(14),A,X(34),A);
 PUT SKIP EDIT((36)'*')(X(14),A);
 PUT SKIP(5) EDIT ('STRATUM   SAMPLE SIZE  PERCENTAGE')
                 (COL(16),A);
 PUT SKIP EDIT((36)'-')(X(14),A);
 PUT SKIP(2) EDIT('   A',SDAY(1),SDAY(1)*100.*RAM/TOTAL,'%')
                (COL(16),A,F(12),F(13,2),A);
 PUT SKIP(2) EDIT('   B',SDAY(2),SDAY(2)*100.*RAM/TOTAL,'%')
                (COL(16),A,F(12),F(13,2),A);
 END;
 END ISAMPLE;
*PROCESS,A,X,AG,FLOW;
 LEAP:PROCEDURE(TEST,N) ;
 DCL (TEST, N) FIXED BIN(31);
  IF MOD(TEST,4)¬=0 THEN  N=0;
                   ELSE IF(MOD(TEST,100)=0 & MOD(TEST,400)¬=0)
                          THEN N=0;
                          ELSE N=1;
  RETURN;
  END LEAP;
*PROCESS,A,X,AG,FLOW;
 WEEK:PROCEDURE(X,Y,Z) ;
  DCL (X,Y) FIXED BIN(31),Z FIXED BIN (31);
   Z=MOD((X+Y+FIXED((X-1)/4)-FIXED((X-1)/100)+FIXED((X-1)/400)),7);
   RETURN;
  END WEEK;
*PROCESS,A,X,AG,FLOW;
 RANDM:PROCEDURE(DSEED,N,R);
 DCL (N,I)FIXED BIN(31),R FLOAT BIN(31);
 DCL (DSEED,D2P31M,D2P31) FLOAT(16);
 (NOFIXEDOVERFLOW): D2P31M=2147483647.; D2P31=2147483648.;
   DSEED=MOD(16807.*DSEED,D2P31M); R=DSEED/D2P31;  RETURN;
 END RANDM;
```

The Forest Service, U.S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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Field and Laboratory Evaluations of Insecticides for Southern Pine Beetle Control

CONTENTS

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FIELD AND LABORATORY EVALUATIONS OF INSECTICIDES FOR SOUTHERN PINE BEETLE CONTROL

Edited by
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ABSTRACT.—Reports results of laboratory screenings and field studies of insecticides for use against the southern pine beetle. Preventive as well as remedial efficacy were observed, along with phytotoxicity to pine and understory hardwood species, effects of insecticides on soil microbial and mesofaunal populations, and degradation of insecticides by selected soil microbes.
Keywords: *Dendroctonus frontalis*, efficacy, microbial degradation, phytotoxicity, adjuvants, lindane, chlorpyrifos, chlorpyrifos-methyl, fenitrothion.

PREFACE

In 1974 the U.S. Department of Agriculture initiated the Combined Forest Pest Research and Development Program, a interagency effort that concentrated on the Douglas-fir tussock moth in the West, on the gypsy moth in the Northeast, an on the southern pine beetle in the South. The work reported in this publication was funded in whole or in part by the Ex panded Southern Pine Beetle Research and Application Program.

Within the Program, a toxicants working group was one of seven such ad hoc groups organized. Each working group con sisted of a subject area coordinator and the funded investigators working on projects directly related to the subject area. Th groups interacted as needed to discuss approaches, share results, and review progress.

This publication reports on insecticide research undertaken by projects in the toxicants working group between 1974 an October 1980. It is intended as a compendium of such research. Techniques and results reported should be useful to futur research on chemical control of pine bark beetles.

Investigators who have contributed to this report are:

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INTRODUCTION

Outbreaks of southern pine beetle (SPB), *Dendroctonus frontalis* Zimmerman, occur almost every year somewhere in the Southern and Southeastern United States. Although direct chemical control of SPB is often impractical, such control is appropriate in some instances. This is particularly true for high-value trees of parks, yards, campgrounds, seed orchards, and other special-use forest areas.

At the beginning of the Expanded Southern Pine Beetle Research and Application Program, only benzene hexachloride and its gamma isomer, lindane, were registered for the control of SPB. Because of possible environmental and human safety considerations, their continued availability for insect control was under question. An objective of the Southern Pine Beetle Program was, therefore, to register two additional insecticides for use against SPB.

The strategy of the first field season was to test an insecticide that had shown potential against western bark beetles. Concurrently, an extensive screening program began to identify compounds that were highly toxic to the SPB, low in mammalian toxicity, and environmentall acceptable. Based on the screening tests, field tests for de termining preventive and remedial efficacy were estab lished in Louisiana, Mississippi, Georgia, and North Caro lina. Remedial applications were against established SP broods in previously attacked trees, while preventive ap plications were on unattacked pines.

Other studies included: the dissipation of spray res dues from pine bark with and without adjuvants, the depo sition of insecticidal sprays on pine bark with conven tional and antidrift systems; the development of a tech nique for assessing preventive efficacy; the assessment c insecticidal impacts on forest soil microbial and mesofaunal populations; the degradation of insecticides by selecte soil microbes; the phytotoxicity of insecticides toward tw pine species and understory flora; the assessment of partia tree-bole sprays for preventing SPB attack.

Some of the studies did not produce results that can b applied in SPB control, but these are included so tha future researchers might benefit from them.

SCREENING TESTS

F. L. Hastings, A. S. Jones, C. K. Franklin

TOPICAL TESTS

PROCEDURES

Test insects were obtained from infested bark of loblolly pine, *Pinus taeda* L., growing in the North Carolina Piedmont. Beetles were collected with light traps beneath 0.74 m^3 fiberboard drums containing the infested bark. Conditions in the emergence chambers were maintained at 26° ± 2°C and > 90 percent relative humidity (RH). All compounds were freshly prepared in reagent-grade acetone at concentrations expressed by weight. Each was applied topically as a 0.25-μl droplet to the thorax of adult beetles with a Burkard Arnold Microapplicator and 30-gage needle. Beetles were treated within 4 hours of emergence, placed in a mixture of freshly ground phloem and bark, and held at 20° ± 1°C and 100 percent RH. Control insects were treated with acetone only and held under similar conditions. Each experiment was replicated from three to eight times on different days, and 5 to 11 concentrations of each insecticide were tested. In calculating mortality after 48 hours, moribund insects were considered dead. Dosage-mortality regression curves were computed by standard methods (Daum 1970). Relative potency was calculated based on lindane toxicity.

RESULTS

When the holding chambers were evaluated, more than 90 percent of untreated adult beetles survived through 72 hours. In the experiments, survival of the acetone-treated insects at 48 hours always exceeded 90 percent.

Table 1 shows the topical lethal dose (LD) values. The most toxic compound, the synthetic pyrethroid (permethrin), was 14 times as toxic as lindane at all LD values. The next best, the organophosphate chlorpyrifos-methyl, was 10 times more toxic than the standard lindane. Seventeen insecticides were more toxic than lindane toward this insect at LD_{50}. These results indicate that several insecticides might be effective replacements for lindane and BHC against the SPB.

A number of these 17 compounds were not further tested for the following reasons: (1) The LD_{90} values of methomyl and aminocarb are much higher than that of lindane. (2) Carbofuran is too toxic to mammals. (3) Diazinon does not persist long enough on the bark to be effective (Brady and Berisford 1977). (4) Stirofos will not be manufactured for field use. The compounds tested are listed in the bolt bioassay section.

In two instances where the phosphorylalkoxy substitution was compared, (*O,O*-dimethyl vs. *O,O*-diethyl), the *O,O*-dimethyl substitution resulted in good selectivity ratios, LD_{50} rat:LD_{50} insect (Kenaga and End 1974). Selectivity ratios for pirimiphos-methyl and pirimiphos-ethyl were 229 vs. 16, while for chlorpyrifos-methyl and chlorpyrifos, ratios were 278 vs. 16.

BOLT BIOASSAYS

PROCEDURES

The 12 insecticides that were bioassayed for contact toxicity to SPB included one synthetic pyrethroid (permethrin), 10 organophosphates (chlorpyrifos, chlorpyrifos-methyl, etrimphos, fenitrothion, phosmet, pirimiphos-ethyl, pirimiphos-methyl, carbophenothion, naled, dicrotophos) and one chorinated hydrocarbon (lindane). All compounds were formulated as emulsifiable concentrates (EC). A microencapsulated formulation of phosmet (encap) was also tested.

We selected trees for the bioassay from active SPB spots around the Research Triangle Park area in central North Carolina. They were loblolly pine and shortleaf pine, *P. echinata* Mill., 15 to 30.5 cm d.b.h. with indications of heavy attack over most of the length of the trunk. We chose only trees in which the majority of beetles were late instar larvae or pupae. Field crews felled and cut suitable trees into 0.5-m bolts and numbered them consecutively, beginning at the base of the trunk. A sequential sampling technique using a 5-cm section from each end of each bolt provided an X-ray estimate of beetle density (larvae, pupae, and adults).

Four treatments—2, 1, 0.5, and 0.25 percent concentrations of the test insecticides—were randomly assigned to the bolts. Untreated bolts served as controls. Lindane at 0.5 percent (the registered dosage) served as a standard for comparison of efficacy.

Freshly prepared aqueous insecticide solutions containing 2.0 percent (w/v) active ingredient were applied to the bolts with a Kinkelder® low-volume sprayer calibrated to wet a bolt just to runoff in 40 seconds. To provide uniform spray coverage, the bolts were rotated on a turntable during the application. The concentration range was obtained by spraying the bolts for 40, 20, 10, and 5 seconds to give 2, 1, 0.5, and 0.25 percent concentrations, respectively.

The sprayed bolts were enclosed in cylindrical cages made of No. 32 mesh Saran® screen and hung on frames under a mature loblolly canopy to simulate field conditions. Emerging beetles were collected daily from each bolt and the number of dead and live beetles recorded. Each Tuesday and Wednesday, the live beetles were held in the laboratory for 48 hours and any additional mortality was recorded. The purpose was to assess whether these live beetles represented a threat of further attack.

The experimental design for the remedial bioassay was a completely randomized design with 42 treatments. A general least squares analysis was done for each of the following response variables: (1) percent mortality in the subsample of beetles held for 48 hours after emergence; (2) percent mortality of emerging beetles, corrected for 48 hours mortality; and (3) percent mortality in the bolt.

Duncan's multiple range test was applied to all response variables showing significance in the least squares analysis to rank differences among the treatments. In addition, the relationship between the X-ray estimate of number of beetles in the bolts and the number that actually emerged was examined, and a linear regression fitted: total emerged beetles = a + b (X-ray estimate of number of beetles).

RESULTS

Table 2 presents the results of the least squares analysis. The differences between treatments were highly significant for percent mortality in the subsamples held in the laboratory for 48 hours after collection (PerDed-48). This result confirmed the importance of assessing the longevity of beetles emerging from treated bolts. Duncan's multiple range test was performed to compare treatments (table 3). Mortality ranged from 100 percent for 2 percent chlorpyrifos-methyl to 4 percent for 0.25 percent carbophenothion. The formulation of phosmet (EC) was not significantly different from the control at any concentration while all four concentrations of chlorpyrifos-methyl, chlorpyrifos, and permethrin were significantly different. The permethrin concentrations were inadvertently cut in half; therefore, the concentrations were 1, 0.5, 0.25, and 0.12 percent. In comparison with the standard (0.5 percent lindane), three treatments—1 percent and 2 percent chlorpyrifos-methyl and 2 percent chlorpyrifos—had significantly higher mortality after 48 hours.

We calculated the percentage mortality of beetles in the bolt (PerDedBo) as follows: the number of beetles in the X-ray estimate minus the total number of beetles which emerged was divided by the X-ray estimate of number of beetles in the bolt. The least squares analysis of this variable showed no significant treatment differences. Duncan's multiple range test indicated that only 2 percent chlorpyrifos-methyl was significantly different from the controls. Interestingly, in the 0.5 percent, 1 percent, and 2 percent phosmet (EC) and 2 percent pirimiphos-ethyl treated bolts, total emergence actually exceeded the X-ray estimate. It is possible that with chlorpyrifos-methyl at the highest concentration, some fumigant action occurred and with phosmet, a flushing action.

A third response variable, percent total mortality (PertDead), was calculated by multiplying the mortality observed for emerging beetles by a correction factor for the additional mortality observed in the subsamples held for 48 hours. Treatment effects were also highly significant for this variable. Table 4 shows Duncan's multiple range test for this variable. The ranking of treatments for this response variable is very complex, with 16 different ranges of significance. Here, 2 percent chlorpyrifos and 2 percent fenitrothion were outstanding, with 95 percent and 94 percent mortality, respectively. Also, there was no significant difference between 0.25 and 0.5 percent carbophenothion and the controls.

Eleven treatments were significantly better than 0.5 percent lindane. They included 1 and 2 percent concentrations of chlorpyrifos-methyl, chlorpyrifos, fenitrothion and etrimphos; and the 2 percent concentrations of pirimiphos-ethyl and the microencapsulated formulation of phosmet. At the 0.5 percent concentration, only chlorpyrifos was significantly better than lindane.

Our results may provide some insight into lindane's erratic performance in SPB suppression efforts in recent outbreaks; the recommended concentration killed an average of only 61 percent of the emerging beetles.

Arc sine transformations were performed on the percent mortality data, but we saw no differences in results of the statistical analysis.

EFFICACY STUDIES: PREVENTION

C. W. Berisford, U. E. Brady, G. E. Fitzpatrick,
C. K. Franklin, F. L. Hastings, A. S. Jones, J. H. Lashomb,
R. F. Mizell III, W. W. Neel, and I. R. Ragenovich

PROCEDURES

Based on results of the screening tests, four insecticides (chlorpyrifos, chlorpyrifos-methyl, fenitrothion, and carbaryl) were further tested to establish their efficacy for both prevention of SPB attacks and remedial control of beetles in infested pines. Efficacy tests were carried out in North Carolina by Hastings, Jones, and Franklin; in Georgia and South Carolina by Berisford and Brady; in Mississippi by Mizell, Lashomb, Fitzpatrick, and Neel; Berisford and Brady; and in Louisiana by Ragenovich.

Aqueous sprays of 0.5 percent lindane were the standard, or reference, in all efficacy tests. All test insecticides were mixed as aqueous sprays. Oil sprays were excluded because of their possible phytotoxic effects, their expense in operational conditions, and the relative ease in mixing waterbase sprays in remote field locations.

The relative effectiveness of insecticides in preventing SPB attack was estimated in three types of experiments: (1) forced-attacked tests, (2) hanging-bolt tests, and (3) standing-tree tests. Uninfested, standing loblolly or shortleaf pines were thoroughly sprayed with hydraulic sprayers operated at 200 to 300 lb/in^2. Depending on the type of test, bolts were either cut from felled trees or the trees were left standing.

Forced-attack tests were used by Hastings and others in North Carolina with chlorpyrifos-methyl and by Berisford and Brady in Georgia with chlorpyrifos and chlorpyrifos-methyl. Field-sprayed bolts of 0.5-m length were taken to the lab where their cut ends were coated with paraffin to reduce moisture loss. Five pairs of newly emerged SPB adults were confined on each test bolt by No. 32 mesh Saran screen. After 25 days the bolts were peeled and the number of successful attacks, the number of live and dead beetles, and the lengths of egg galleries were recorded.

In hanging-bolt tests, 1.5- to 2-m-long bolts were cut from the field-sprayed trees and taken to sites adjacent to natural infestations of SPB (Berisford and others 1980). The bolts were attached to uninfested trees and hung at about 3 m above the ground. One or two bolts per tree were used. A 20- by 50-cm (1,000 cm^2) wire-screen sticky trap was fastened to each bolt to monitor SPB visitation. Each bolt was also baited with frontalure (a 1:2 mixture of frontalin and α-pinene) to invite attack. Frontalure was released from 2-dr vial caps or from cigarette filters (Gammill and others 1978). After 25 to 30 days, workers removed the bolts and recorded numbers of SPB trapped on screens. They also delineated a 1,000-cm^2 area opposite the sticky trap, peeled the bark, and recorded numbers of SPB attacks and total lengths of egg galleries. Hanging-bolt tests were done with all four insecticides in each of the five States.

The survival, or death, of living sprayed trees is the ultimate criterion of prevention of SPB attack. Standing-tree bioassays were used with chlorpyrifos and chlorpyrifos-methyl in Mississippi. Treatment trees were selected near SPB infestations that had at least 25 currently infested trees larger than 15 cm d.b.h. and no less than 23 m^2/ha of pine basal area. The treatment trees were within 100 m of the actively infested trees, and there were green unattacked

pines between the infestations and the treated trees. The unattacked trees served as a reservoir to maintain the SPB infestation for the duration of the test.

Standing unattacked treatment trees were sprayed to the point of runoff. Spray was applied to the boles of the trees up to a height just above the lowest major live limbs (usually 9 to 12 m above the ground). Unsprayed check trees were designated. Both loblolly and shortleaf pines were used as treatment and check trees. A sticky trap similar to those used in the hanging-bolt tests was immediately placed on each study tree at 3 to 3.5 m above the ground. Frontalure release devices were attached to each trap to attract SPB. The traps were inspected and the attractant replenished every 2 to 3 weeks. Crown color, presence of pitch tubes, and proximity to newly attacked trees were recorded for each tree.

RESULTS

North Carolina.—Figure 1 presents field bioassay data comparing chlorpyrifos-methyl at 0.5 and 1 percent to the standard, 0.5 percent lindane. In general, neither concentration of chlorpyrifos-methyl appeared to be a reasonabl[e] replacement for lindane as a preventive treatment. The 0.[5] percent concentration was comparable to lindane durin[g] the first 2 months, whereas the 1 percent concentration wa[s] only comparable during the first month. During the thir[d] and fourth months, neither concentration of chlorpyrifos-methyl was effective, but after 5 months, both concentrations, as well as lindane, significantly reduced gallery lengt[h] ($P < 0.05$). In the sixth month, 0.5 percent chlorpyrifos-methyl and lindane were significantly better than either th[e] controls or 1 percent chlorpyrifos-methyl. Beetle activit[y] in the area then declined, and no further testing was possible until 15 months later. At this point, only lindane continued to show activity against the SPB (gallery length significantly reduced as compared to control and chlorpyrifos-methyl treatments ($P < 0.05$).

The laboratory "forced-attack" data (table 5) may explain, in part, the erratic field results. In particular, the two 1 percent chlorpyrifos-methyl bolts for month 2, which had galleries totaling 280 cm, were from the same trees as the two field bioassay bolts that had 3,208 cm, or 71 percent of the galleries. These figures suggest that these trees were

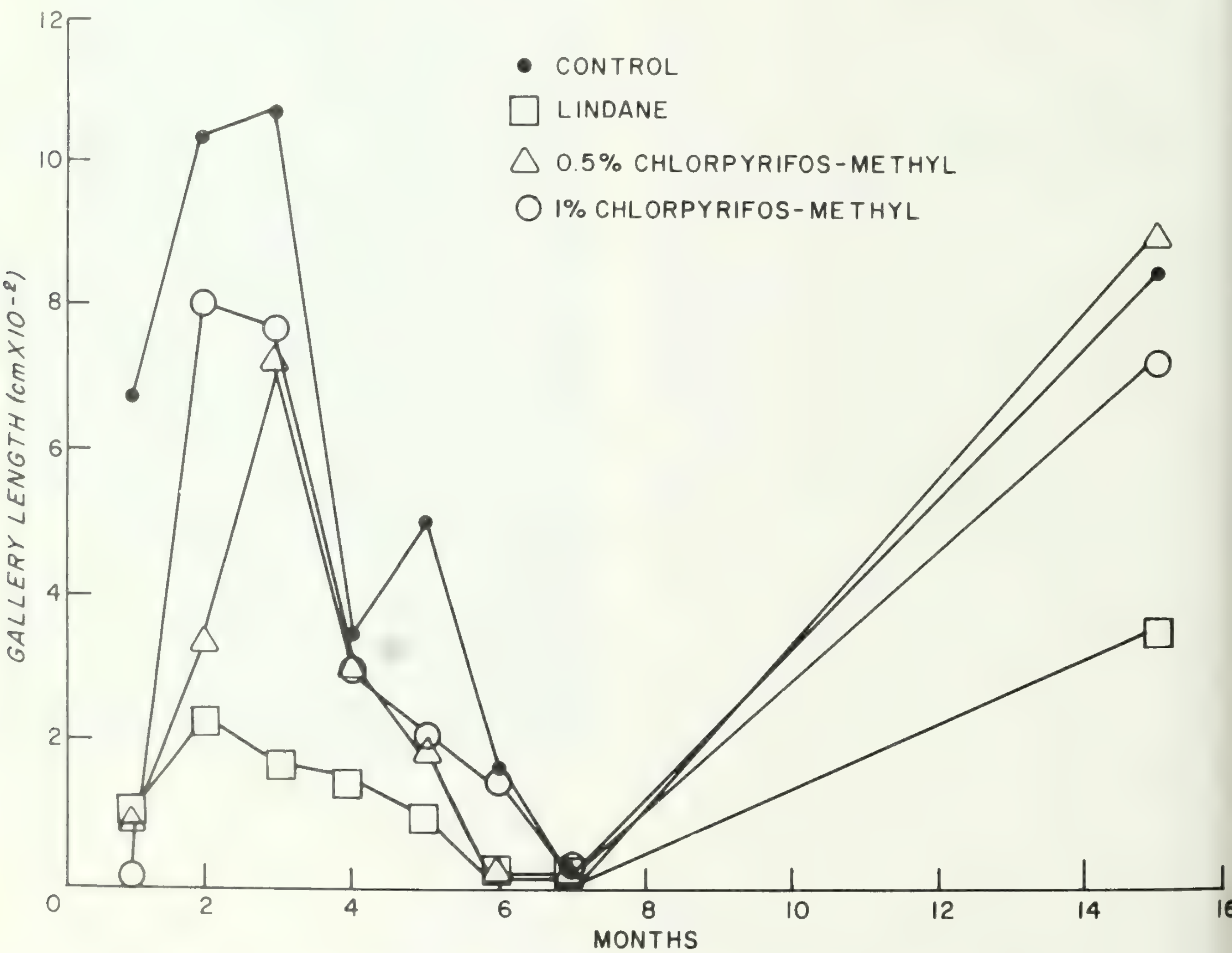

Figure 1.—Time-course experiment comparing the reduction in SPB gallery length with treatment.

not sprayed at all. Throughout the experiment, attack was heavier on the bolts sprayed with 1 percent, suggesting that spray coverage in this plot may have been erratic. The poor performance of the 1 percent chlorpyrifos-methyl in the field test but not in the lab during months 2 and 3 may have been caused by rain removing the insecticide from the field bolts. The area in which the bolts were hung received 12.2 and 11.2 cm of rain during these 2 months. Brady and Berisford[1] have found that chlorpyrifos-methyl can be washed off trees by simulated rainfall even after the spray has dried.

Georgia.—Tables 6 and 7 show that bolts treated with 1 percent fenitrothion had a few SPB attacks and some egg gallery construction at 0-day and a significant number of attacks and gallery length at 2 months. Bolts treated with 2 percent fenitrothion had some attacks but no successful gallery construction until the 4-month bioassay. Attacks and gallery construction of 2 percent fenitrothion at 4 and 6 months indicate that it is probably not an effective preventive control beyond 3 months where SPB pressure is high. Few attacks and no gallery construction occurred on bolts treated with 0.5 percent lindane.

Preliminary tests with two formulations of carbaryl showed that 2 percent Sevimol 4® and UCSF-2 were ineffective at 0-day (tables 6 and 7). Carbaryl was not effective in preventing attack with bark residues of over 3,500 p/m in 0-day bioassays (table 8).

Residue levels through 4 months (table 8) show that fenitrothion may be ineffective if bark residues are below 3,500 p/m. Very low concentrations of lindane residues, however, continue to prevent successful gallery construction (tables 6,7,8).

Table 9 shows the number of SPB caught on sticky traps attached to the chlorpyrifos, chlorpyrifos-methyl, and lindane-treated standing trees. Sites 2 and 3 received moderate pressure during the first 2 months. On site 1 only small, but consistent, numbers of beetles were attracted to the trees. Because no one has determined the number of SPB required to successfully attack and kill a tree, we do not know if enough beetles were present to kill trees on any of the treatments in this spot. However, some untreated trees not included in the test were killed during the study.

All untreated controls in site 2 had died by 16 weeks after treatment, and one tree treated with 1 percent chlorpyrifos-methyl also died. This spot expanded rapidly, and the active front moved away from the treated trees by 26 weeks.

SPB activity ceased at site 3 within 42 weeks. Three untreated controls died by 24 weeks, and all died by 34 weeks after treatment. No trees that had been treated with an insecticide, at any rate, died in this spot.

Table 10 gives bark residues for the four collection dates. Residues for both lindane and chlorpyrifos were similar to those found in previous studies. About 25 percent of the residue at 0-day remained after 12 months.

Although most treatments protected treated trees, the results should be evaluated cautiously. The relatively small numbers of SPB on sticky traps and the general decline of beetles in the area indicated light attack on most trees. Large numbers of SPB and heavy mass attacks might have successfully overwhelmed the insecticide barrier. These results should not be extrapolated to an epidemic situation.

Mississippi.—Twelve Mississippi study sites were evaluated at regular intervals for up to 1 year after trees were treated with chlorpyrifos and chlorpyrifos-methyl. Two of the sites did not have sufficient SBP activity to kill control trees and, therefore, were deleted from further analyses.

Cumulative means of numbers of SPB trapped per tree on each site during the period after spraying are given in figure 2. Variation among sites was very high. For instance, at 30 days, the mean number of SPB trapped per tree ranged from 10 at site 5 to several hundred at sites 1, 10, 11, and 12. The high numbers of active trees and SPB trapped during the study indicate that the experiments rigorously tested the treatments.

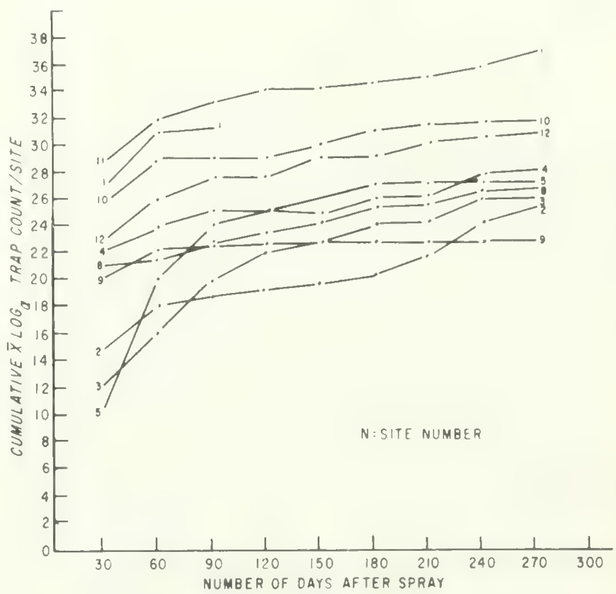

Figure 2.—Cumulative mean number of SPB relative to number of days after treatment.

The presence of pitch tubes on trees usually indicates successful SPB attack. In this study, however, pitch tubes on trees protected by insecticides were not reliable indicators of tree mortality. Figure 3 shows that within 60 days all control trees had pitch tubes; all of these trees died. By contrast, pitch tubes continued to increase in treated trees (70 percent or more had pitch tubes at test termination), but fewer than 58 percent were killed.

The true measure of insecticide efficacy against SPB is prevention of tree mortality. Tree mortality is indicated by a change in crown (needles) color from green to yellow or red. Evaluation of insecticidal performance was based on

[1] Brady, U. E., and C. W. Berisford. 1977. Insecticidal protection of high value pines against the southern pine beetle and other beetles. Expanded Southern Pine Beetle Research and Application Program final report. 18 p. [Personal communication.]

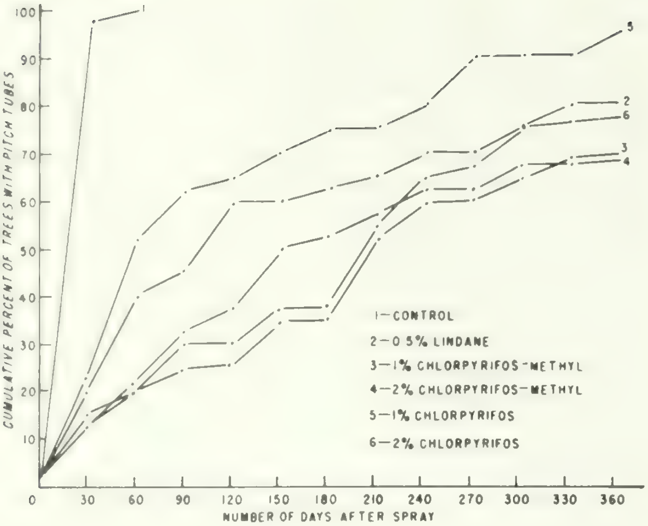

Figure 3.–Occurrence of pitch tubes on trees after six insecticide treatments.

the mean number of days after treatment (control vs. treatment trees) that crown-color change was noted in the trees that died.

Mortality of trees treated with insecticide and control trees occurred continuously during the test period. The variation in time to tree death and crown-color change can be attributed to number and time of beetle mass attack by site, season of the year, individual tree differences, site differences, and interaction of these factors. The important point, however, is that the treatment trees on the average lived longer than did the controls under similar conditions.

Table 11 gives the mean number of days to crown-color change and the number of trees killed in each treatment. All control trees in each of the 10 plots succumbed at a mean 81 days after treatment. The mean time to crown-color change was significantly longer for trees in all insecticide treatments. The failure of this measure to differentiate between insecticidal concentrations suggests that crown-color change may not be precise enough to effectively evaluate insecticidal performance. In studies where number of successful attacks and egg-gallery lengths were measured, the effects of different insecticidal concentrations were discernible (tables 12 and 13).

Table 12 gives results of another series of field efficacy tests of chlorpyrifos and chlorpyrifos-methyl on standing trees in Georgia. Numbers of successful attacks and SPB egg-gallery lengths show that 1 percent and 2 percent chlorpyrifos and chlorpyrifos-methyl were generally as efficacious as 0.5 percent lindane up to 4 months after treatment. At 8, 10, 12, and 15 months after treatment, 1 percent chlorpyrifos was less effective than other candidate formulations. Lindane (0.5 percent) was superior to all other materials 12 and 15 months after application. The time during which lindane is effective in preventing SPB attacks is similar to the protection provided for other species of pine bark beetles (Berisford and Brady 1976; Smith 1970). Overall, chlorpyrifos-methyl tended to provid[e] slightly more protection than chlorpyrifos.

Table 13 gives results of forced-attack tests. Conclusions drawn from these data are similar to those from th[e] field bioassays. Based on number of successful attacks an[d] length of egg galleries 6 and 12 months after treatment, [2] percent chlorpyrifos was generally more effective than [1] percent chlorpyrifos or 0.5 percent lindane. Laborator[y] bioassays were deemed unnecessary in 1976 due to the success of field bioassays in prior tests and the agreement o[f] results with both bioassay techniques.

In another series of Mississippi tests, the standing tree method was used to test fenitrothion. For this test three types of information are presented: (1) time of occurrence of pitch tubes on the treated trees, (2) the mortality of trees in each of the treatments through time and (3) trap counts through time as a measure of beetle occurrence on the treated trees.

The standing-tree prevention test is highly conservative because treated trees were constantly baited with SPB pheromone, and beetles came to the trees continuously. Thus, a tree was never allowed to fully recover from previous SPB attacks. This situation would not occur in a natural stand where SPB attack en masse over a brief period.

Occurrence of pitch tubes (fig. 4) can be considered a helpful early predictor of the efficacy of an insecticide treatment. Pitch tubes developed immediately on the control trees; 100 percent had pitch tubes 2 months after treatment. Pitch tubes occurred later on treated trees, appearing first on those receiving 1 percent fenitrothion and later on those receiving 2 percent fenitrothion or lindane. By 6 months after treatment, all the treated trees had pitch tubes. In view of this time data, it was assumed that more of the control trees and 1 percent fenitrothion-treated trees would be killed and that these trees would die sooner than

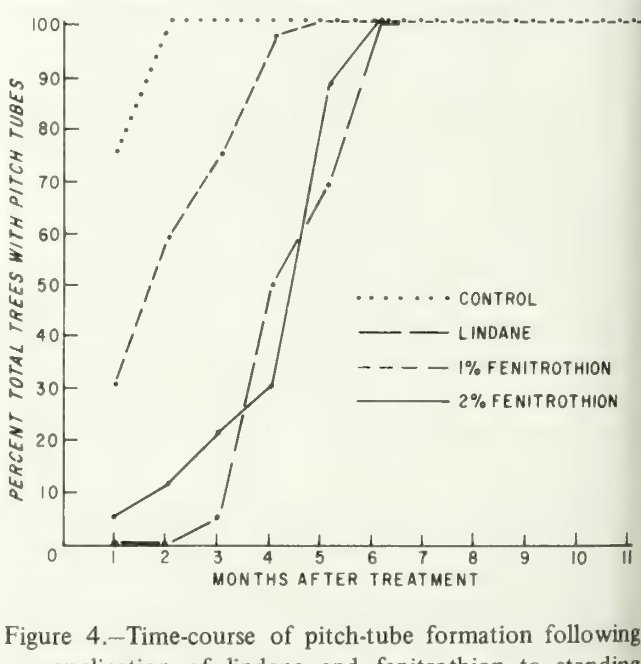

Figure 4.–Time-course of pitch-tube formation following application of lindane and fenitrothion to standing trees in Mississippi.

trees receiving 2 percent fenitrothion or lindane. This assumption was correct.

Figure 5 shows the time of death and percentage of trees in each treatment that were killed during the test. Of the 32 control trees, 84 percent were killed during the test (100 percent if the two sites with lowest beetle pressure are disregarded); 75 percent of these were dead after 3 months. Only 9 percent of the trees receiving the 1 percent fenitrothion treatment had died 5 months after treatment. Most were killed more than 7 months after treatment, though only 34 percent died in all. Lindane and 2 percent fenitrothion were much more effective against SPB. Only 3 percent (one tree each) of the 2 percent fenitrothion and lindane-treated trees were killed in the test, and both died more than 8 months after treatment.

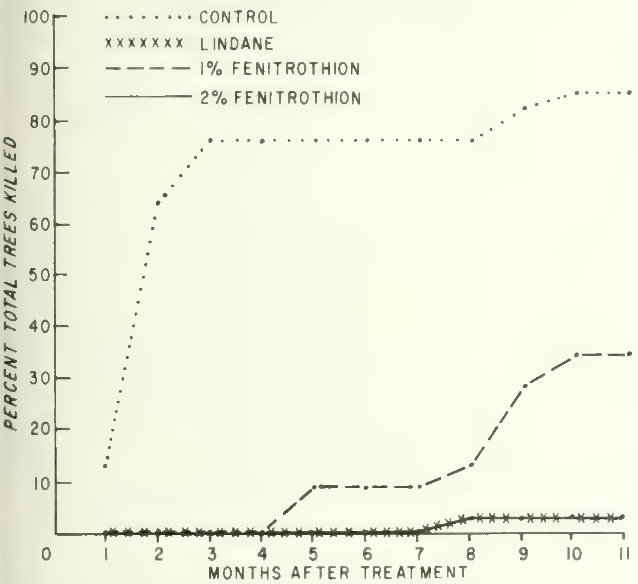

Figure 5.—Time-course of tree mortality following application of lindane and fenitrothion in Mississippi.

It should be pointed out that the eight test sites were sprayed from early May to early June 1978. Thus, from 6 to 7 months after treatment, cold winter weather occurred in Mississippi, slowing SPB activity and probably prolonging the life of some of the 1 percent fenitrothion-treated trees. However, prevention of attack from SPB for 6 months would cover the normal peak period of SPB activity in the Southeastern United States.

To determine how long insecticide protection lasted, we studied the mean number of beetles trapped (± standard deviation) from the time of treatment to the death of the tree or the end of the test (table 14). The counts suggest that the beetle populations at six of eight sites were high enough to test the efficacy of the insecticide treatments. Since not all control trees were killed at two of the sites (14, 20), these sites were eliminated from the analysis.

Variation between sites and among trees within sites was large (table 14). Mean trap counts of the trees in each of the four treatments show that control trees were killed by lower numbers of beetles on the average than were required to kill trees receiving the 1 percent fenitrothion treatment. More importantly, the numbers of beetles that killed the control trees early did not kill the treatment trees: the controls lasted only 2 months, while no 1 percent fenitrothion-treated trees were killed until 5 months after treatment. Because treated trees were constantly baited and subjected to continuous attack, it can be concluded that 1 percent fenitrothion protects trees for up to 4 months and that 2 percent fenitrothion and 0.5 percent lindane give protection for up to 10 months.

The hanging-bolt method was also used to test fenitrothion in Mississippi. Results were comparable to those from the standing-tree method. Numbers of SPB on the bolt traps were similar to those on the standing-tree traps (table 15), indicating that the treatment bolts were exposed to high populations of attacking SPB.

The number of successful attacks per bolt and centimeters gallery construction in each of the treatments varied with time after treatment. Soon after the first month after treatment, trees receiving 1 percent and 2 percent fenitrothion, and lindane, had significantly lower numbers of attacks and centimeters of gallery than the controls.

At 4 months after treatment, the number of successful attacks was not significantly different between controls and trees receiving 1 percent fenitrothion ($P < 0.05$). Values were significantly lower ($P < 0.05$) for trees receiving 2 percent fenitrothion and lindane. Gallery construction after 4 months was significantly lower ($P < 0.05$) in all treated trees than in the controls. Gallery construction in the bolts treated with 1 percent fenitrothion was higher than in bolts treated with 2 percent fenitrothion and lindane.

Results 10 months after treatment were similar to the 4-month results for the 1 percent fenitrothion treatment. After 10 months, the 2 percent fenitrothion and lindane treatments failed to prevent SPB attack but were still significantly better ($P < 0.5$) than controls.

Louisiana.—The hanging-bolt method was used in Louisiana to determine the ability of chlorpyrifos to prevent SPB attack. Sets of bolts were treated and weathered for multiples of 30 days before exposure to beetles. Thus, it was possible to determine how soon treatments became ineffective. Attack was measured by two methods. First, while the bolts were hanging on the trees, the numbers of attacks, as evidenced by entrance holes and boring dust, were counted weekly. These data were used to determine the length of time the treatments prevented beetles from attacking. Second, bark was peeled from a section and gallery lengths were measured. Gallery length was an indicator of successful beetle attack.

Two-factor ANOVA (treatment vs. time; treatment vs. site) were conducted. Three measured variables—trap catch, attacks on bolts, and gallery length—were considered in the analyses. Trap catch was used to determine the presence of SPB. Attack and gallery length were measures of treatment

fect. Treatment significantly affected all variables in the vo-factor ANOVA.

Numbers of beetles trapped varied significantly over me, but the lack of significant interactions of the variables iggests that trap catches were associated with changes in opulation densities over time, and not with time since eatment. In other words, equal numbers of beetles were vailable to attack each treatment at any given time.

In the ANOVA for treatment vs. time, there was a sig- ficant interaction for the adjusted attack variable. This teraction implies a change in the effectiveness of the eatments over time.

The effects of treatments over time (one-way ANOVA) vealed no significant differences between lindane and 1 nd 2 percent chlorpyrifos in prevention of attack for up to months (fig. 6). After 3 months there was no significant ifference between treatments in preventing attack. The 0.5 ercent chlorpyrifos treatment prevented attack for the rst month only.

In terms of gallery length, lindane and 1 and 2 percent hlorpyrifos provided protection for the 7 months of the st (fig. 6). The 0.5 percent chlorpyrifos prevented gallery onstruction for 3 months.

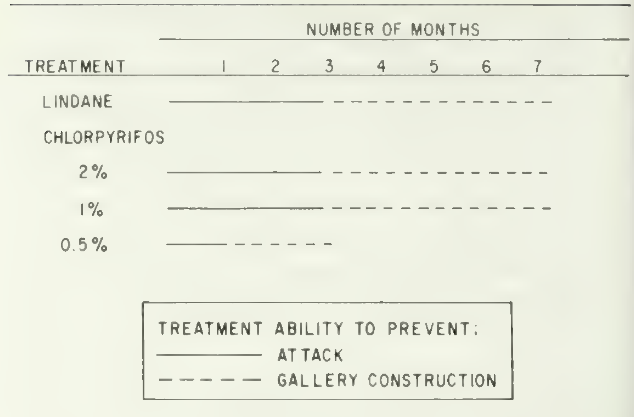

Figure 6.—Length-of-time treatments prevented SPB attack and gallery construction.

EFFICACY STUDIES: REMEDIAL

C. W. Berisford, U. E. Brady, G. E. Fitzpatrick, J. H. Lashomb,
R. F. Mizell III, W. W. Neel, and I. R. Ragenovich

PROCEDURES

The same four insecticides that were tested for prevention were also field-tested for their remedial effectiveness against SPB populations in attacked trees. Aqueous sprays were used in all remedial tests.

Remedial tests were designed to test the efficacy of the four test compounds for killing larvae, pupae, and adults of SPB within trees. Bolts were cut from naturally infested loblolly and shortleaf pines in Louisiana, Georgia, South Carolina, and Mississippi. The d.b.h. of sample infested trees ranged from 15 to 24 cm, and trees contained predominantly late-stage larvae, pupae, and/or brood adults. Three bolts were cut from each tree: one from the lower, one from the middle, and one from the upper one-third of the infested bole. The bolts were initially cut to 1-m lengths. Bark samples were removed from the ends of the bolts, then the bolts were trimmed to ½-m lengths. Beetle numbers in the bark samples were estimated by hand dissection or by use of radiographs.

All three bolts from a tree were given the same treatment. In Georgia, the standing infested trees were sprayed with a hydraulic sprayer; in all other remedial tests, the bolts were sprayed after being cut from the trees. The sprayed bolts were placed in Saran screen rearing bags or ventilated rearing cans (Berisford and others 1976). Emergent beetles were collected and counted periodically over a span of 30 days. In some studies, live emergent beetles were placed in paper ice-cream cartons that contained moist toweling and coarse sawdust. Survival of these beetles was recorded at 12-hour intervals for 72 hours.

RESULTS

Georgia and South Carolina.—Table 16 shows the results of remedial control assays in Georgia and South Carolina. In terms of dead larvae, pupae and adult in treated trees 5 days after spraying and numbers of adults emerging, 0.5 percent chlorpyrifos was less effective than 0.5 percent lindane for remedial control. The 1 percent and 2 percent chlorpyrifos were about as effective as 0.5 percent lindane.

In two different tests in Georgia (table 17), 1 and 2 percent fenitrothion reduced emergence of SPB from treated bolts, and mortality of emerging adults was high for both concentrations. A maximum of 18 percent of emerging adults survived for 72 hours with 1 percent fenitrothion. Lindane reduced emergence of SPB, but a higher percentage of emerging beetles survived for 72 hours. It appears that 1 percent and 2 percent fenitrothion are superior to 0.5 percent lindane for remedial control (fig. 7).

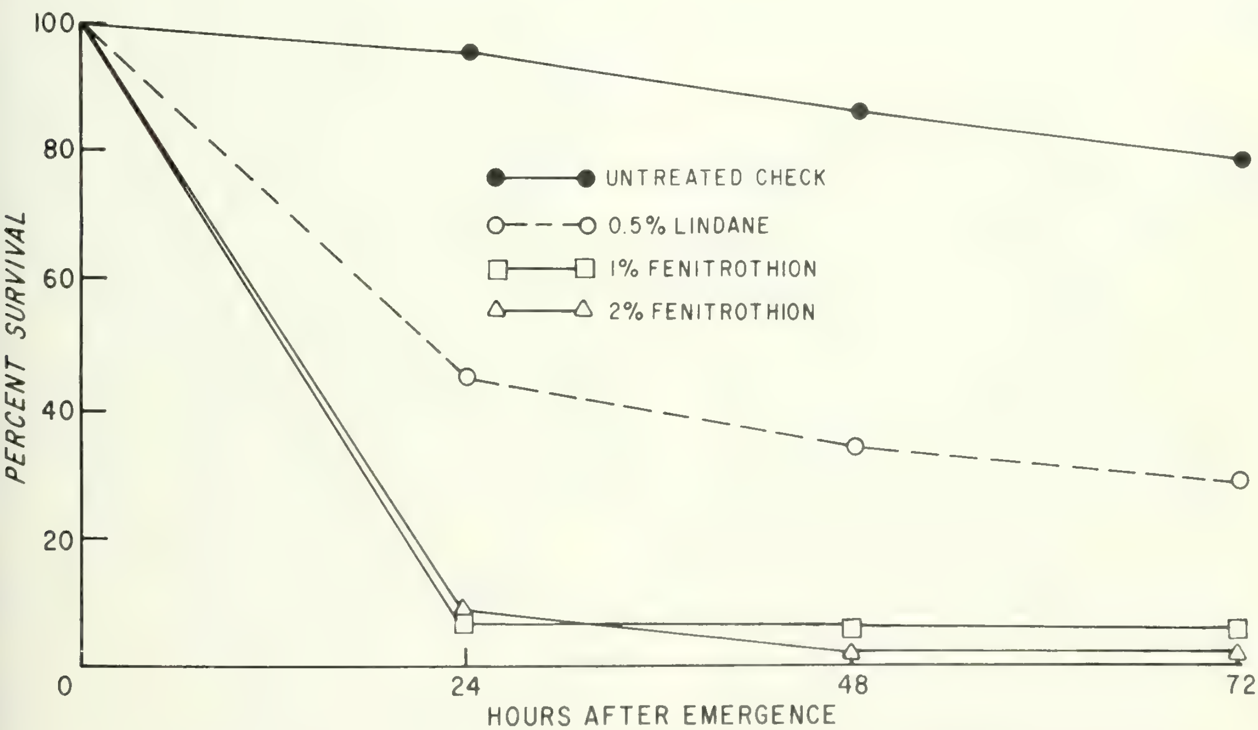

Figure 7.—Comparison of remedial control of SPB by fenitrothion and lindane in Georgia.

Mississippi.—SPB emergence from bolts treated with enitrothion and lindane varied greatly (table 18). In terms of survival, the 1 and 2 percent fenitrothion treatments performed as well as lindane, if not better. Lindane was shown by Bennett and Pickard (1966) and Jump and Tsao (1973) o be effective as a remedial treatment for SPB. In all three reatments, survival percentages were much lower than in he untreated trees. It should be pointed out that mortality data and beetle emergence were monitored once every 24 hours. Therefore, a 24-hour error could exist in the actual ength of beetle survival after emergence.

As a remedial treatment, 1 and 2 percent fenitrothion were equally effective and as good as, if not better than, indane in killing emerging beetles.

Louisiana.—Treatments significantly affected emergence at the 0.05 confidence level. No other effects were tatistically significant. Table 19 shows the total number of beetles emerging from the treatment bolts and the average number of emerging beetles/0.09 m^2 (1 ft^2) of bark surface. Difference between means for each of the chlorpyrifos treatments, and the control and lindane were subjected to *t*-tests. The two chlorpyrifos treatments were not compared. Both concentrations of chlorpyrifos were better than the control, and the chlorpyrifos treatments were as effective as lindane. Duncan's multiple range tests confirmed this result. Figure 8 shows the average number of emerging beetles/0.09 m^2 of bark surface for each replication. Lindane and 1 and 2 percent chlorpyrifos consistently reduced numbers of emerging bark beetles. Although statistical tests did not show that the 0.5 percent concentration of chlorpyrifos was significantly poorer than higher concentrations, the graph suggests that the lower concentration gives less consistent control.

The arc sine transformation showed that all treatments reduced the proportion of the initial brood that emerged per unit area of bark surface. The strength of this test is limited by several factors associated with the X-rays. Timing of the X-rays or dead brood may result in a less than accurate picture of the initial beetle population. However, the estimated average number of brood per unit area and the average number of emerging beetles per unit area for each treatment can be combined to estimate percentage of emergence.

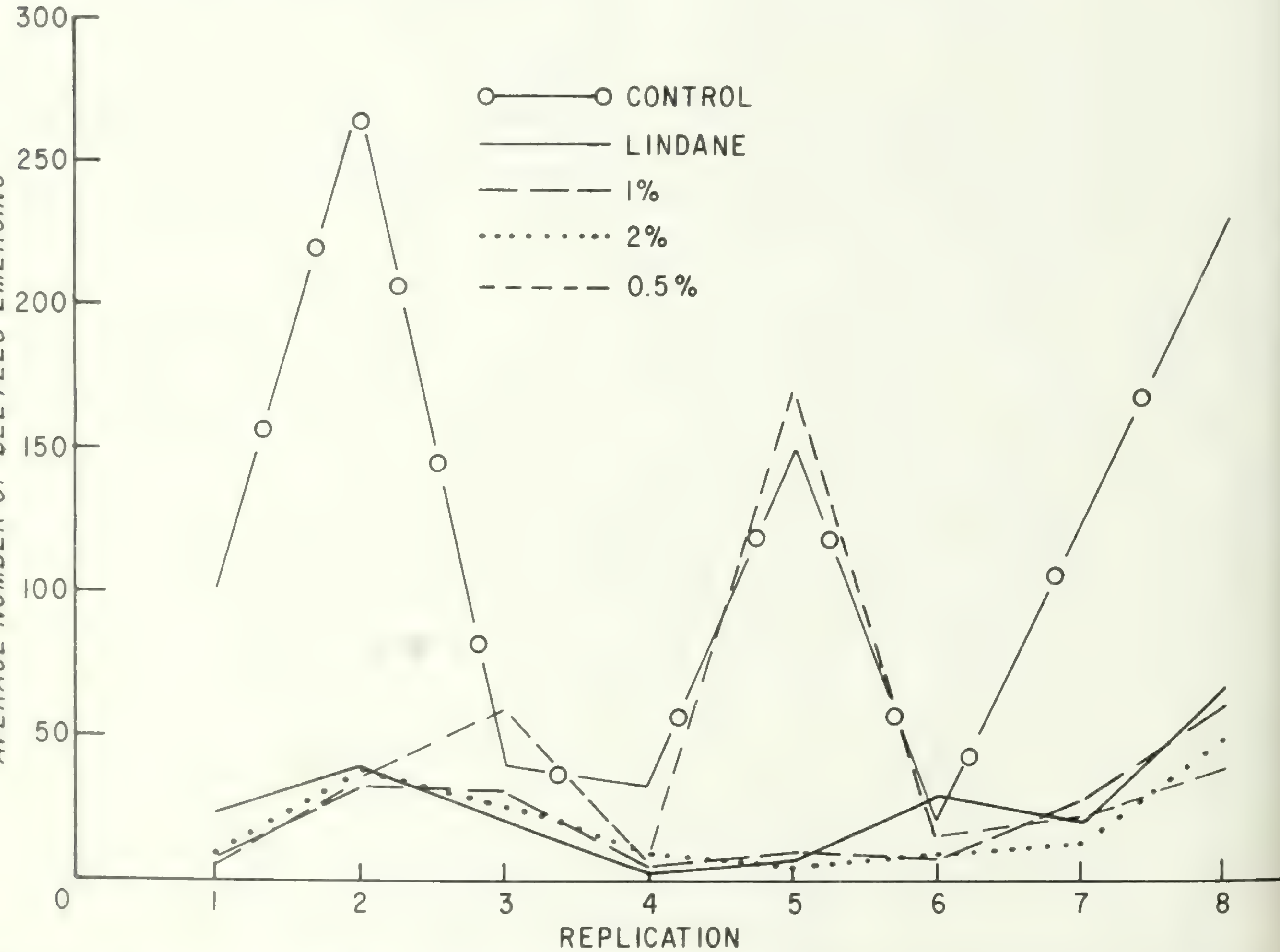

Figure 8.—Average number of SPB emerging/ft^2 of bark surface from bolts treated with chlorpyrifos for remedial control, Louisiana.

RESIDUE STUDIES

C. W. Berisford, U. E. Brady, and I. R. Ragenovich

PROCEDURES

Persistence of insecticide on bark was determined by gas liquid chromatographic (GLC) analysis. Samples of approximately 100 g (ca. 50 cm^2) of the outer 1.27 cm of bark were removed and stored at −20° C until prepared for analysis. Samples were taken 1 to 2 m above ground in standing trees and from the lower, middle, and upper bole of fallen trees.

Samples were chopped in a Hobart food chopper, and two 5-g subsamples were leached for 24 hours in 40 ml of solvent (hexane for lindane and ethyl acetate for chlorpyrifos, chloripyrifos-methyl and fenitrothion). Extraction efficiency of leaching was 95 percent and was comparable to that of blender maceration in replicated tests. Aliquots of each of these extracts were dried with Na_2SO_4 and analyzed by GLC as follows:

Lindane.—Electron capture detector; oven, 210°C; 6-ft glass column packed with 1.5 percent OV-17 and 1.95 percent QF-1 on Chromasorb W.

Chlorpyrifos, chlorpyrifos-methyl, and fenitrothion.—Flame photometric detector, P mode; oven, 190°C, column, 1-ft glass, packed with 5 percent DC-200 on Chromasorb Q.

Carbaryl.—Electron capture detector; column, 145° to 150°C; detector, 225°C; inlet, 170°C; 0.3-m by 4-mm glass column packed with Chromasorb Q 80 to 100 mesh support coated with 3 percent Silicone SE-30; carrier gas flow (N_2), 120 ml/min.

Losses of lindane and chlorpyrifos-methyl from bark following simulated rain were also estimated. Insecticides were applied (three replications) by compressed-air hand sprayers. Table 20 indicates elapsed time between insecticide application and simulated rain (manual sprinkling) as well as volume of water applied per ft^2 (0.09 m^2) of bark. Bark samples were removed 1 hour after the "rain" and analyzed for insecticide content according to procedures described previously.

The effects of adjuvants on deposition and persistence of bark sprays were also determined. Adjuvants, marketed as sticking agents, and antidrift additives were applied to standing loblolly pines as recommended by the manufacturer with 0.5 percent lindane and 1 percent chlorpyrifos. Low-drift spray systems tested were from Delavan Manufacturing Co. and Velsicol Chemical Co. (Accutrol® spray system).

For quantitative evaluation of spray drift, four experiments were conducted in an open field upwind from a rectangular grid system composed of 48 numbered sample collection stations on stakes spaced 5 m apart (length: 8 stations; width: 6 stations). In each experiment the spray gun of each system was stationed 5 m upwind at varying positions, depending on wind direction, along the first row of a six-station side of the grid. Spray containing 0.5 percent lindane wettable powder (WP) and an appropriate amount of the dye to ensure visibility of spray on the collection cards was directed upward and almost perpendicular to the field surface, while a predetermined equal volume of spray was dispensed from each gun. Kromekote cards and cards for GLC analysis of lindane were collected at each sampling station after spray application for subsequent drift analysis. For quantitative evaluation of toxicant deposition and persistence, five loblolly pines were treated with 0.5 percent WP lindane by the Accutrol system. An equal number of trees were similarly treated by conventional spraying. Samples of bark from each tree were collected at 0-day and at 2 months for quantitation of lindane by GLC analysis. Bark residues were determined, by the techniques previously described, on the day of application and 2, 4, 6, and 9 months after treatment.

A simple test was done to determine the amount of chlorpyrifos that rubs from treated bark surfaces onto clothing. Pieces of cotton cloth 12 cm^2 were rubbed over bark surfaces treated with each chlorpyrifos concentration according to the schedule in table 21. Samples were taken by firmly rubbing the cloth over the treated bark surface immediately after spraying (wet) and 2 hours after treatment (dry). The cloth was then folded several times with the contacted surface to the inside, tied, and stored in a freezer. All samples were placed in large culture tubes and extracted with 40 ml ethyl acetate for 48 hours. They were then dried with Na_2SO_4, and appropriate dilutions were made and analyzed as previously described.

RESULTS

Chlorpyrifos was much more persistent on pine bark than lindane, while chlorpyrifos-methyl was intermediate in persistence (table 22). The rate of dissipation of both chlorpyrifos and chlorpyrifos-methyl was independent of dosage at the concentrations tested.

There appeared to be no correlation between preventive efficacy of these materials (tables 12 and 13) and their persistence on bark (table 10). Considering the greater toxicity of both chlorpyrifos and chlorpyrifos-methyl than lindane in topical toxicity tests (Hastings and Jones 1976), it is surprising to find that lindane, while apparently less persistent than chlorpyrifos and chlorpyrifos-methyl, is superior to both materials in providing long-term protection against the SPB. The amount of lindane calculated from residue analysis to be present on bark 6 months after treatment with 0.5 percent lindane was 0.05 percent. This concentration of lindane was less effective immediately after applications than the 0.5 percent lindane 6 months after application. One possible explanation, consistent with the data, involves the alteration of lindane to a more toxic

oduct during exposure under field conditions. A second ssible explanation is that a significant amount of lindane ay have been bound and not extractable by leaching or aceration of bark. Experiments on dissipation of ^{14}C dane from bark under appropriate conditions are in ogress to test this possibility.

When bark residues of fenitrothion were below 3,500 m, beetles constructed galleries (tables 15 and 23). ndane, however, continued to prevent gallery construcon at very low residues.

In bioassays immediately after treatment, bark resies containing over 3,500 p/m of carbaryl failed to prent attack (table 7).

Chlorpyrifos-methyl, emulsifiable concentrate (EC), s readily lost by sprinkling water over bark 10 minutes or hours after application of insecticide (table 20). In comrison, lindane (EC) levels at 2 hours were essentially affected by washing; 17 percent was lost by sprinkling 10 inutes after application (WP). Loss of lindane (WP) was proximately twice that of lindane (EC) at the 10-minute ash time. Chlorpyrifos-methyl is obviously quite pertent in bark if rain does not occur for an extended time ter treatment. However, these test results show that loss chlorpyrifos-methyl from treated trees would be large if in occurs shortly after application.

Adjuvants applied to increase persistence of chlorrifos and lindane were generally only slightly effective r intervals up to 9 months after treatment. Plyac® was e most effective of the six sticker materials tested (table). No efficacy tests were carried out with these adjuvantsecticide mixtures.

Drift of lindane (0.5 percent WP) applied as a spray by o foam spray systems was only slightly less than with a nventional spray system.

Preliminary results of comparison of sprays prepared om EC and WP formulations of lindane indicated that the P formulation was most compatible with all of the lowift systems. The desired foam generated by these spray systems was at least partially destroyed by the EC formulation. Consequently, WP formulation was used in all subsequent experiments.

Quantitative comparisons of spray drift generated from three spray systems were made by GLC analyses of lindane residues at each of 48 sampling stations in the downwind spray pattern of each system (table 25). Comparative drift with each system was evaluated also by use of dyed spray on Kromekote cards at each sampling station. Results are in general agreement with those obtained by GLC analyses.

In three experiments with each spray system, results indicate that the drift range from the conventional spray system was not significantly different from the Accutrol or the Delevan foam systems. Both foam systems utilized Accutrol adjuvant. To the contrary, the degree of drift based on visual observations during spray applications appeared to be reduced by each foam system. Although results indicate general agreement between the Kromekote and GLC assay systems, the GLC method is considerably more sensitive (Barry and others 1978) and in completed analyses, spray drift was detected at certain distant stations by GLC and not by the Kromekote assay.

Deposition and persistence of lindane (0.5 percent WP) on pine bark with the Accutrol system was no greater than that obtained with the conventional system. In five replications with each system, 2,531 ± 414 p/m lindane was deposited on bark with the Accutrol system compared with 2,962 ± 355 p/m with the conventional system. At 2 months after treatment, results of GLC analyses indicated that about 60 percent of the lindane applied by each system had dissipated.

The cloth contamination tests were done in Louisiana and Georgia. Table 26 shows the results of these tests. As would be expected, the amount chlorpyrifos rubbed off the bark increased as the concentration applied to the bark increased. Also, the amount removed by rubbing was considerably higher when rubbing was done before the treated bark had dried. This study indicated that after chlorpyrifos dries, it constitutes no human health hazard by contact.

SOIL MICROBE STUDIES

A. S. Jones and F. L. Hastings

PROCEDURES

Microbial studies were conducted on (1) effects of chlorpyrifos and fenitrothion on soil microbial populations, (2) metabolism of fenitrothion by forest soil fungi, and (3) metabolism of chlorpyrifos by pure cultures of forest soil fungi.

Effects on soil microbial populations.—Flasks were prepared by mixing 20 g of air-dried soil with 0, 1, 10, 50, and 100 p/m active ingredient (a.i.) of technical insecticide and adding distilled water to bring the soils to approximately field capacity.

After the mixture incubated for 2 or 4 weeks at room temperature (approximately 25° C), 100 ml of sterile distilled water was added to each flask and the soil suspension stirred on a magnetic stirrer for 15 minutes. Using sterile distilled water, dilutions of 1:50,000 were made for fungi and 1:500,000 for bacteria and actinomycetes. For each replicate, five plates each of Martin's Rose-Bengal Agar and Thornton's Agar were prepared for the fungi and bacteria, respectively. Colonies were counted after incubation at room temperature for 7 days. In addition, a time-course study was done with one soil, sampled before and 1, 7, and 14 days after the treatment with the various concentrations of chlorpyrifos and fenitrothion. This study provided additional information on stimulation and/or depression of bacterial and fungal populations. Table 27 characterizes the soils used in this study.

Metabolism of chlorpyrifos by forest soil fungi.—For the metabolic studies, Erlenmeyer flasks containing 50 ml of Czapek-Dox Broth (Difco Lab., Detroit, Mich., pH 7.3) were autoclaved, and 2.5 mg of ^{14}C-labeled chlorpyrifos was added aseptically to each flask. Liquid scintillation counting (LSC) of 1 ml aliquots established the initial level of radioactivity (cpm) for each culture flask. Three replicate flasks were then inoculated with four fungi, *Trichoderma harzianum, Penicillium multicolor, P. vermiculatum*, and a *Mucor* sp. Uninoculated flasks served as controls. After the selected incubation time, the flasks were harvested by homogenization and filtration of the mycelium onto a weighed filter paper. The culture filtrate was then extracted with methylene chloride, and the radioactivity in the organic and aqueous phases was determined by LSC. Thin-layer chromatography (TLC) and radiochromatographic scanning were used to locate and identify the insecticide and its metabolites, using known standards as references. This experimental procedure was repeated for 7-, 14-, and 28-day incubation times.

Aerobic soil metabolism of fenitrothion and chlorpyrifos.—A soil sample was taken from a loblolly pine stand on the laboratory grounds at Research Triangle Park, and the percentage of moisture was determined. Fifty g dry weight of soil was placed in each of four Erlenmeyer flasks. One flask was autoclaved for 30 minutes, weighed, and the moisture content readjusted; after 24 hours, it was re-autoclaved for 60 minutes to provide a sterile control soil. The insecticide solution was prepared by dissolving 12.5 mg of analytical-grade insecticide in 10 ml of the stock solution of ^{14}C-labeled insecticide, filtering the solution through a 0.2 μ Millipore filter, and washing with an additional 10 ml of 95 percent ethanol. Four-ml aliquots of the resultant sterile solution were aseptically pipetted into the three remaining flasks and mixed with the soil to give a concentration of about 10 p/m. Each flask was "stoppered" with a trapping tower (Marvel and others 1978) and incubated at about 25°C for 28 days. The Drierite® moisture-trapping layers were changed as needed, and the Ascarite® CO_2 trap was changed after 7 days incubation and analyzed for $^{14}CO_2$ as described by Marvel and others (1978).

After 28 days of incubation, the trapping towers were dismantled and analyzed for trapped organic volatiles and $^{14}CO_2$, and the soils were extracted with 200 ml of ethyl acetate. The ethyl acetate extracts were concentrated to 25-ml and 10-μl aliquots counted by LSC. The soil was sampled for bound residues by combusting duplicate 200-mg subsamples and counting the $^{14}CO_2$ released. Gas chromatography of the ethyl acetate extracts was performed on a Tracor 560 with a flame photometric detector.

RESULTS

Effect on soil microbial populations.—In general, we saw no adverse effect on either fungi or bacteria from concentrations of fenitrothion ranging from 1 to 100 p/m (table 28). The various soils differed in the number of microorganisms per gram and in type of effect seen, but only in soil 4 at 100 p/m was there a significant reduction in population counts. In all other instances, the effect was a stimulation of population counts, usually at 10 or 50 p/m. In soil 6, the number of fungi increased with increasing concentration from 1 to 50 p/m and was still elevated at 100 p/m.

Table 29 records the effect of chlorpyrifos on soil microbial populations. In soil 2, numbers of fungi decreased significantly with increasing concentrations of chlorpyrifos, while at 1 p/m a significant increase in bacterial colonies was seen. In soils 3, 4, and 5 the differences were not significantly related to the concentration of chlorpyrifos.

Table 30 shows populations of fungi isolated from a single soil treated with fenitrothion and chlorpyrifos and incubated for 1, 7, and 14 days. Data on effects of treatment and incubation time was subjected to analysis of variance F test and Duncan's multiple range test.

For chlorpyrifos, the analysis of variance indicated that incubation time was much more significant than treatment

P = 0.003 and P = 0.1679, respectively). When Duncan's multiple range test was applied to data for each day, only the 50-p/m concentration of chlorpyrifos at day 7 was significantly different from the control. Examination of the data suggests that one replicate in that series had a very low colony count.

The analysis of variance for fenitrothion showed a small treatment effect as well as the strong incubation time effect ($P = 0.0494$ and $P = 0.0003$, respectively). Duncan's multiple range test applied to data from each day indicated that at day one, 100 p/m fenitrothion had significantly increased the colony count. Smaller increases seen at the lower concentrations were not significantly different from the controls. By day 14, the colony counts for 50 and 100 p/m were significantly lower than in the control. However, the mean colony count over the 14 days of incubation was not significantly different for any treatment (Duncan's multiple range test). This fact, coupled with the increases seen at day 1, and the lack of adverse effect in the previously described studies with five different soils, indicates that fenitrothion itself is not toxic to soil fungi at concentrations up to 100 p/m. The decline in numbers seen at 100 p/m in the time-course study at 7 and 14 days is more probably explained as a natural decline in populations caused by the exhaustion of available nutrients in the soil by the early, rapid growth of the population at this concentration.

Aerobic soil metabolism of fenitrothion and chlorpyrifos.—Studies using ^{14}C-labeled fenitrothion and chlorpyrifos in sterile and nonsterile soil were run to determine whether soil microorganisms can metabolize these insecticides and to identify degradation products. In a preliminary study using soil from the Research Triangle Park area, only the parent compound, fenitrothion, was recovered after 28 days incubation.

Another soil metabolism study using ^{14}C-labeled chlorpyrifos and fenitrothion was established and incubated for 56 days. At the end of the incubation period, the treatment and sterile control flasks were analyzed for trapped volatilized insecticides, ^{14}C-labeled CO_2 produced by metabolism of the insecticide molecules, organic solvent extractable residues of parent compound and metabolites, and unextractable bound residues. Total recovery of radioactivity from the samples was 85, 86, and 81 percent for the sterile control and the two treatment replicates, respectively. Of the applied radioactivity, 53, 55, and 55 percent, respectively, was extracted with organic solvent from the control and treatment replicates, while the soil-bound fractions contained 32, 31, and 26 percent. A trace of radioactivity was recovered as $^{14}CO_2$ in the treatments only, and no radioactivity was found in the traps for volatilized insecticides. TLC and LSC of the organic extracts indicated that about 46 to 47 percent of the applied radioactivity was present as parent compounds after 56 days of incubation in both control and treatment flasks. Approximately 12 percent of the radioactivity in the organic extract of the control flask was found in three breakdown products. Approximately 15 percent of the organic extracts from the treatment flasks was found as breakdown products. Although the half-life of the two insecticides in this experiment was approximately 56 days, breakdown appeared to be primarily the result of chemical action as opposed to microbial degradation, since the sterile control showed similar disappearance rates and products.

Metabolism of chlorpyrifos by forest soil fungi.—Table 31 presents the results of the time-course study on the metabolism of chlorpyrifos in pure cultures of four soil fungi grown in Czapek's medium. It is difficult to draw any conclusions from this experiment due to the rapid loss of the radioactive label from the system. A 30 percent loss of radioactivity from all flasks, including the sterile controls, occurred after only 7 days; by day 28, over 70 percent was lost. This loss was probably the result of very rapid volatilization of the parent compound, chlorpyrifos, from an aqueous medium (personal communication, Dow Chemical Co.). TLC of the organic and aqueous extracts of the cultures after the various incubation intervals revealed only chlorpyrifos in the organic layer and only 3, 5, 6-trichloro-2-pyridinol in the aqueous layer. Although there appeared to be more of the water-soluble product in the *Penicillium* and *Mucor* cultures, definitive conclusions on the relative importance of chemical and microbial degradation of chlorpyrifos cannot be made until a method is found to reduce the volatility of chlorpyrifos in an aerobic aqueous system.

SOIL AND LITTER MESOFAUNA STUDIES

F. L. Hastings, A. S. Jones, and C. K. Franklin

PROCEDURES

In a field study, the effects of lindane (0.5 percent) and chlorpyrifos-methyl (0.5 and 1 percent) on mesofauna in forest litter were evaluated. Plots for litter and soil sampling were established in each of the treatment and control sites on lines between trees selected for the field test. Fifteen samples each of forest floor (litter) and soil from each treatment plot were collected a week prior to the insecticide spray to establish pretreatment population levels of five categories of animals: (1) orbatid mites, (2) mesostigmatid mites, (3) trombidiform mites, (4) collembolans, and (5) other arthropods (e.g., ants, beetle larvae, aphids).

From the same sites, samples were taken 1, 6, 23, and 75 weeks after treatment to monitor any population decreases and to track subsequent fauna recovery.

Samples were collected with a brass ring 3 cm deep and 20 cm^2 in area. The ring was placed on the forest floor and a cut made around the outside edge down to the mineral soil. The floor from within the ring was removed and placed in a plastic bag. Next, a small block of hardwood was placed on the ring and tapped with a hammer until the top of the ring was at the top of the mineral soil. The ring and enclosed soil were lifted with a squared-off trowel, and the approximately 60-cm^3 sample was placed in a plastic bag. Samples were placed on modified Tullgren funnels for 7 days and then ovendried. The percentage of soil moisture was calculated on an ovendry basis. Invertebrates driven from the samples were caught in alcohol vials and classified by microscopic examination.

The persistence of insecticide residues associated with mesofaunal populations was also determined by GLC. Soil and litter samples were homogenized in a Waring® blender, and 25- and 50-g subsamples (respectively) were extracted two times with solvent (acetone for chlorpyrifos-methyl and hexane for lindane). The extracts were concentrated to 1 ml and analyzed with a Hewlett-Packard® model 7620 gas chromatograph. Conditions for analysis were:

Flame-ionization detector oven-programed from 180° to 290° C at 20°/min after an initial isothermal run of 10 min for lindane and 15 min for chlorpyrifos-methyl; 6-ft by 1/8-in stainless steel column packed with 2 percent OV-17; injector temperature 200° C; detector temperature 300° C.

Peaked areas were quantified by comparison to standard curves, and retention times were verified with standards run during the analysis and with spiked samples.

RESULTS

Tables 32 and 33 indicate changes in numbers of soil and litter invertebrates during 75 weeks after application of lindane (0.5 percent) and chlorpyrifos-methyl (0.5 percent and 1 percent). Data are expressed as number of organisms per sample volume. Values are corrected for pretreatment levels and moisture content in computing statistical significance.

Litter organisms were most prevalent and most affected by insecticidal treatments. The most sensitive organisms appeared to be the collembolans, which were significantly depressed (P = 0.01) by both lindane and chlorpyrifos-methyl 6 and 23 weeks after treatment. Numbers of mites and other organisms were reduced for 23 weeks after treatment; thereafter, they returned to pretreatment levels. Interestingly, these organisms appeared to be affected to the same extent by lindane and chlorpyrifos-methyl. This phenomenon was unexpected because organophosphates are generally not as persistent as organochlorines. However, as table 34 indicates, the 0.5 percent chlorpyrifos-methyl was persistent for at least 5 months in forest litter.

Soil invertebrates were not very numerous and, with few exceptions, were not severely affected by these insecticides. Collembolans appeared sensitive, as in the litter, but recovered by the final sampling period. Mesostigmatid populations were depressed at 6 weeks but were somewhat stimulated at 23 weeks. The residue data indicate that only small amounts of insecticide actually passed through the litter or F layer. This fact, along with the metabolic potential of soil microorganisms in the F layer, probably explains the lessened impact of these insecticides on soil animals.

SELECTIVE APPLICATION OF TOXICANTS

C. W. Berisford and U. E. Brady

PROCEDURES

A study was designed to determine if SPB attacks ld be prevented by selectively applying toxicants to: the tom two meters, the lower half, and top half of tree es. These treatments were compared to entire bole treat-nts which had previously been shown to be effective.

Five treatment blocks were established in three in-ations (Clarke, Morgan, and Oglethorpe Counties, Ga.) ing September–November, 1979. Blocks 1, 3, and 4 arke County) were located in a 40-year-old stand of ed shortleaf and loblolly pines, predominantly the ner (established September 27 and October 17 and 18, ectively). Block 2 (Oglethorpe County) was located in a year-old slash pine (*P. elliottii* Engelm.) plantation (es-lished October 12). Block 5 (Morgan County) was lo-ed in a 30-year-old mixed loblolly pine-hardwood forest ablished November 7). Trees ranged from 20.5 to 29 cm h. and 15 to 24 m total height (means 24.6 and 21.2, ectively). SPB populations in these stands were high.

Each block consisted of three treatments–sprayed al 2 m only, sprayed basal 6.6 m only (considered to lbole of noncrown portion), and sprayed full length, h an additional set of unsprayed trees as controls. Four s received each treatment within each block; 16 trees block and a total of 72 trees were treated. Block 4 uded only the basal 6.6-m and full-length treatments. ated parts of trees were sprayed to runoff at 200 to 300 n^2 pressure with a water emulsion of one of two com-nds–0.5 percent lindane (used in blocks 1 through 4), 2 percent chlorpyrifos (used in block 5). Bark samples e taken about 1 day after spraying for residue analy-o verify spray coverage and concentration.

Alternate trees in each treatment were baited at mid-e with 1 ml of frontalure released from dispensers de-bed by Gammill and others (1978). Baits were re-ed on days 15 and 30 as needed.

A 20- by 50-cm screen trap coated with Stickem cial® was placed at midbole of each tree to monitor tle visits. Traps and trees were inspected at 15-day rvals following treatment, and evidences of beetle at-k and estimates of SPB trapped on screens were re-ded. On day 45, screens and baits were removed from all s and absolute counts were made of SPB trapped.

On day 60, one tree from each treatment and block felled and bark samples taken at 2-m intervals along the e beginning at 1 m: Presence or absence of any SPB life ge (parent adult, egg, larval instar, pupa, brood adult) the success or failure of attacks were noted. Attacks e recorded as successful if eggs were present in parent eries.

When SPB activity began in the spring of 1980, a ond series of tests was initiated. Twelve treated trees were sprayed on April 2 in a slash pine plantation. All treated trees were sprayed with lindane above 5 m (mid-bole) up to 11 m on the bole. Four untreated trees were marked as checks. Two checks and two treated trees were baited with frontalure. An additional six trees were treated on May 2 from 4 to 10 m above the ground. Three of these trees were baited. Residue samples were taken from all test trees.

A final set of tests was installed on July 14. Six trees each were treated with 0.5 percent lindane on the basal 6 m (lower half), from 5 to 11 m (midbole), or the entire bole. Six untreated checks were designated. Alternate trees were baited with frontalure at midbole. No trees were treated on the basal 1 to 2 m because all previous tests showed this treatment to be ineffective.

RESULTS

Table 35 presents the results of the preventive control tests. During 1979 only trees with 100 percent bole coverage were protected, but two of these trees were at-tacked and one was killed. Subsequent residue analysis indi-cated that this tree was not sprayed. Treated portions of trees sprayed on the basal 2 and 6.6 m were adequately protected (no attacks or gallery construction), but attacks above the sprayed areas resulted in tree mortality. All baited trees receiving less than whole-bole treatments died. About 20 percent of the unbaited trees survived, appar-ently because few beetles attacked them.

The results of these preliminary tests showed that spray coverage higher than midbole was needed for ade-quate protection.

On the test set up on April 2, 1980, all checks were at-tacked and killed by April 28. All treated trees (full height and upper half) were protected with one exception. This tree had two SPB pitch tubes below the treated area on April 28. It was subsequently mass-attacked and killed.

The trees in this series of tests were in areas with high SPB populations. Twenty-seven other unbaited and un-treated trees were killed in this spot during May and June.

The final tests of applications above and below mid-bole produced similar results. All untreated checks and trees treated below midbole were killed and none of those treated above midbole or over the entire bole was killed. One above midbole treatment had an unsuccessful attack (table 35).

Analyses of residues showed deposition of lindane and Dursban® on the sprayed portions of trees to be similar to those in previous studies (Berisford and others 1980; Brady and others 1980; Mizell and others 1981).

Treatment of the basal 2 m, or the lower half, of pine boles provided little or no protection from SPB attack. Treatment of the entire bole into the lower portion (about

20 percent) of the crown provides excellent control, as had been demonstrated in previous tests.

The preliminary data indicate that treatment of the midbole area where SPB attacks are usually initiated (Coulson and others 1976) gives good protection. Effective and ineffective treatments are shown in figure 9. If it proves feasible, utilization of this type of treatment on an operational basis will provide two benefits: (1) It will require less insecticide for protection (about 30 percent less), thereby reducing costs. (2) Because excessive runoff is reduced by not treating the lower bole, contamination of the immediate area and the impact of the toxicants on nontarget organisms will be substantially reduced.

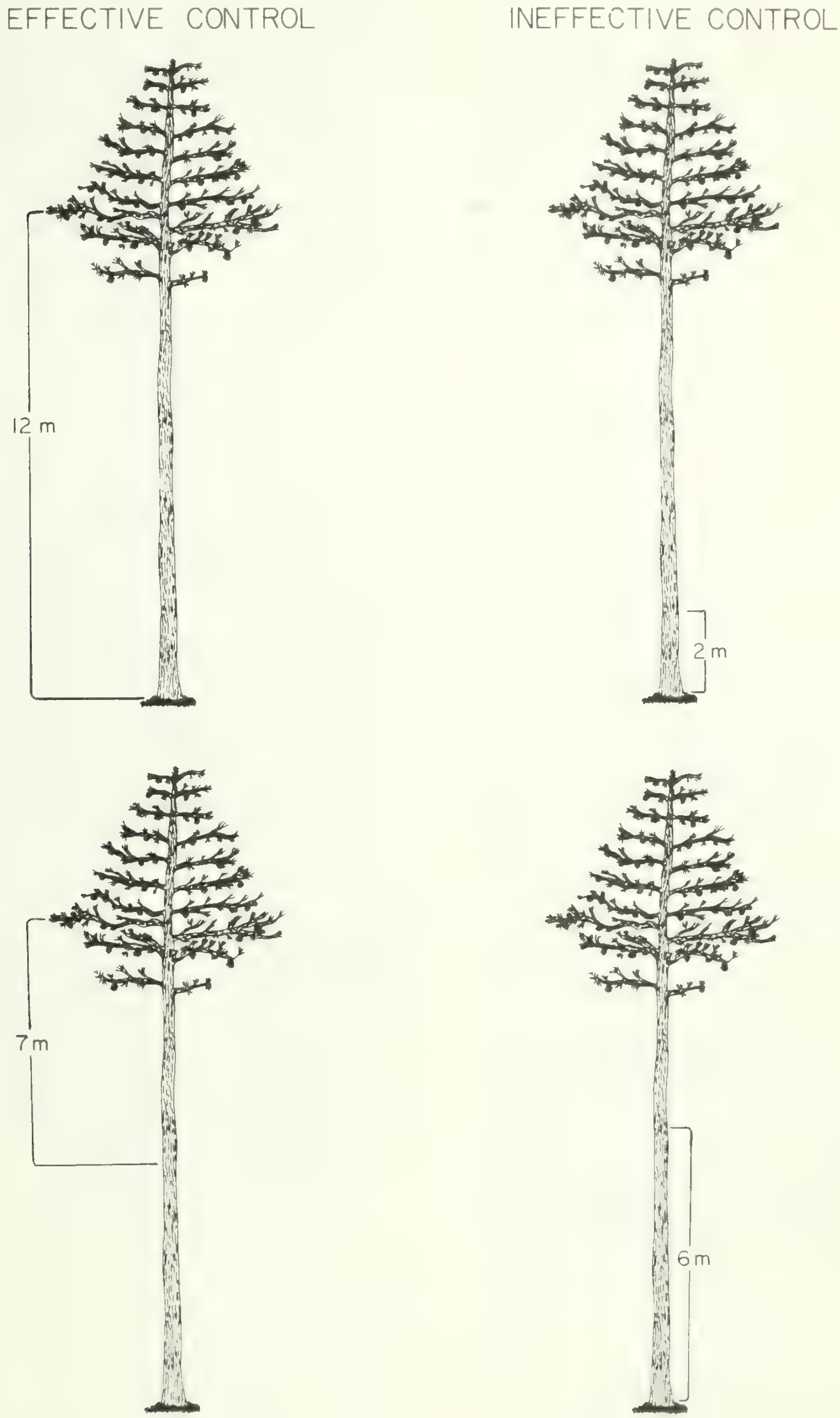

Figure 9.—Sections of bole sprayed with insecticide to prevent SPB damage.

OBSERVATIONS ON PHYTOTOXICITY

F. L. Hastings, A. S. Jones, and C. K. Franklin

High levels (2, 4, and 8 percent) of chlorpyrifos, chlorpyrifos-methyl, and fenitrothion were applied by hydraulic sprayer to the point of runoff on loblolly and shortleaf pines. Neither pine species showed any phytotoxic effect.

The following woody plants were found in the chlorpyrifos and chlorpyrifos-methyl plots in North Carolina: willow oak, *Quercus phellos* L.; post oak, *Q. stellata* Wangenh.; northern red oak, *Q. rubra* L.; sweetgum, *Liquidambar styraciflua* L.; red maple, *Acer rubrum* L.; flowering dogwood, *Cornus florida* L.; winged elm, *Ulmus alata* Michx.; eastern red cedar, *Juniperus virginiana* L.; common chokecherry, *Prunus virginiana* L.; blackhaw, *Viburnum prunifolium* L.; sourwood, *Oxydendrum arboreum* (L.) DC.; blueberry, *Vaccinium* sp.; pignut hickory, *Carya glabra* (Mill.) Sweet; eastern persimmon, *Diospyros virginiana* L.; sassafras, *Sassafras albidum* (Nutt.) Nees; hawthorn, *Crataegus* sp. The fenitrothion plot contained a number of these same woody plants with the exception of post oak, northern red oak, winged elm, chokecherry, sassafras, and blueberry. Additional plants in this plot were white oak, *Q. alba* L.; blackjack oak, *Q. marilandica*; water oak, *Q. nigra* L.; American elm, *Ulmus americana* L.; and black tupelo, *Nyssa sylvatica* Marsh. var. *sylvatica*.

Neither chlorpyrifos nor chlorpyrifos-methyl killed understory plants at either concentration. The only phytotoxic symptoms were leaf kill and dieback in twigs of blueberry. These symptoms were still evident after 1 year.

The 4 percent fenitrothion caused leaf damage to black tupelo, red maple, blackjack oak, and hawthorn. Damage to the red maple was most severe, but no mortality occurred within 12 months after spraying. The 8 percent concentration caused leaf damage to the red maple, blackjack oak, flowering dogwood, sweetgum, and pignut hickory.

SUMMARY

Chlorpyrifos (Dursban 4E) was registered with the EPA in February 1979 for remedial and preventive treatment of pines to reduce damage and possible mortality caused by infestations of SPB. The insecticide is to be applied as a 1 percent aqueous spray to individual trees using suitable hand- or power-operated ground spray equipment. The hanging-bolt bioassay indicated that this concentration protected trees in Georgia from SPB attack and egg gallery formation for 4 months. In Louisiana, protection against attack was for 3 months, and protection from egg gallery formation was for 7 months. In Mississippi, protection from egg gallery formation lasted for approximately 5 months.

In studies of prevention of tree mortality, 1 percent chlorpyrifos was equivalent to lindane in 10 study sites in Mississippi, which were kept under continual attack for up to 1 year. The results were similar in Georgia, although beetle populations were lower.

Remedial studies in which emergence cages or cans were placed in the laboratory indicated 1 percent chlorpyrifos to be equal to lindane, or slightly superior. In studies where emergence was observed outdoors, 1 percent chlorpyrifos was significantly more effective than lindane (94 percent mortality vs. 61 percent).

Phytotoxicity and human-exposure safety data supported this registration. Chlorpyrifos concentrations of 2, 4, and 8 percent were shown to cause no problems in southern pines. There was some burning of understory vegetation; however, no mortality resulted and 12 months after application there was no sign of damage. By wiping a cloth over treated bark, it was shown that after chlorpyrifos dries, it constitutes no human health hazard by contact. This is particularly important for home use.

Other safety data indicated that chlorpyrifos is unlikely to be harmful to soil microbes. However, with one soil which had a high nitrogen content, some reduction in fungal propagules was observed. In this same soil, 1 p/m chlorpyrifos stimulated bacterial growth.

In Georgia, hanging-bolt studies indicated that 2 percent fenitrothion protected trees from attack and egg gallery formation for at least 3 months. The hanging-bolt and standing-tree techniques were compared in Mississippi. Two percent fenitrothion appeared to be effective against SPB for more than 6 months. Efficacy differences might be attributed to differences in beetle populations or weathering effects. Residue studies indicated that fenitrothion persisted longer in Mississippi than in Georgia. Because of the rapid movement of SPB infestations, an insecticide with the safety characteristics of fenitrothion, which is effective for 3 months, is believed to be an appropriate substitute for lindane.

Remedial studies in Georgia, Mississippi, and North Carolina indicated that 1 percent fenitrothion was superior to lindane in reducing survival of beetles emerging from infested trees.

Fenitrothion caused no phytotoxic effects in southern pines sprayed with 4 percent and 8 percent concentrations. There was some leaf damage to understory vegetation, but no mortality was observed after 12 months in red maple, the most severely damaged species.

In general, fenitrothion caused no adverse effects to either fungi or bacteria at concentrations in soil ranging from 1 to 100 p/m. It did reduce fungal propagules somewhat in one soil at 100 p/m, but in many cases population counts were higher.

A highly reproducible, simple, and economical technique (hanging-bolt) was developed for assessing preventive efficacy of insecticides against the SPB. This technique does not require standing trees and thus eliminates the problems

of spot dieout during a test and of obtaining long-term commitments from landowners. This procedure may be useful for testing insecticides against a variety of primary bark beetles.

The laboratory acute toxicity screening indicated that 17 of the 29 materials evaluated were more toxic than lindane against the SPB. Field bioassays showed that nine of these insecticides could replace lindane as a remedial control.

Six adjuvants were tested for increasing persistence of lindane and chlorpyrifos for a period of 9 months. These materials were only slightly effective. Plyac was the most effective of the six sticker materials tested with lindane, while NuFilm® 17 was most effective with chlorpyrifos. No difference in deposition or persistence of lindane was found when the antidrift foam, Accutrol, was compared to conventional hydraulic application.

Chlorpyrifos-methyl (Reldan® 4E) was evaluated in the same manner as chlorpyrifos and fenitrothion in Mississippi and Georgia. These studies indicated that this insecticide was as effective as chlorpyrifos in preventive and remedial SPB control procedures. Lower concentrations of chlorpyrifos-methyl were tested in North Carolina, and results indicated that even 0.5 percent was as effective as lindane for 2 months as a preventive. Because of its efficacy, low mammalian toxicity, and transient effects on litter mesofaunal populations, chlorpyrifos-methyl appeared to be an excellent replacement for lindane. Unfortunately, the producer decided against the field use of this material.

Selective application of toxicants to different parts of pine tree boles indicated that treatment of the basal 2 m or even the lower half of pine boles provides no protection from SPB attack. However, treatment of the upper portion of the bole is as effective as treatment of the entire bole. Data indicate that upper-bole treatment provides adequate protection with about a 30 percent reduction in insecticide. Such treatment can be done at less cost and it has less impact on nontarget areas.

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Appendix

Table 1.–Toxicity of insecticides applied to southern pine beetles[a]

Insecticide	Insects treated	Slope ± S.E.	LD_{50}[b]	95% fiducial limits	LD_{90}[b]	95% fiducial limits	Relative potency[c]	95% fiducial limits
Permethrin	600	2.12 ± 0.22	2.16	1.73-2.56	8.68	7.07-11.47	13.63	–
Chlorpyrifos-methyl	479	2.28 ± 0.71	3.38	2.76-4.12	9.83	6.53-15.0	9.75	7.27-13.09
Stirofos	700	2.73 ± 0.74	4.05	3.41-4.81	11.80	7.41-19.1	8.12	6.12-10.78
Chlorpyrifos	481	3.13 ± 0.40	5.63	4.55-6.97	16.38	9.57-28.5	5.85	4.29-7.97
Naled	880	3.08 ± 0.29	7.45	6.23-8.87	21.69	16.2-29.4	4.42	3.37-5.80
Fenithrothion	995	2.48 ± 0.37	8.66	7.46-10.0	25.20	19.6-32.9	3.80	2.91-4.97
Etrimphos	540	3.27 ± 0.29	8.77	7.26-10.6	25.51	17.9-36.8	3.76	2.81-5.03
Pirimiphos-methyl	600	2.48 ± 0.24	8.97	7.20-11.1	26.11	19.1-36.1	3.67	2.72-4.97
Dicrotophos	840	2.93 ± 0.36	8.99	7.68-10.5	26.15	19.8-35.1	3.66	2.79-4.82
Pirimiphos-ethyl	580	2.87 ± 0.29	10.42	8.11-13.3	30.32	22.3-41.7	3.16	2.33-4.32
Phosmet	600	2.37 ± 0.30	12.51	10.4-15.0	36.42	24.6-54.8	2.63	1.98-3.50
Carbophenothion	440	2.66 ± 0.68	19.37	14.9-25.1	56.38	39.0-82.5	1.70	1.24-2.35
Carbofuran[d]	720	1.77 ± 0.35	22.62	11.1-39.1	119.6	59.0-1,786	1.47	–
Methomyl[d]	559	1.18 ± 0.15	24.72	18.6-31.6	299.1	184-638	1.35	–
Aminocarb[d]	680	1.36 ± 0.24	25.02	16.2-35.1	218.9	118-835	1.33	–
Diazinon	350	2.91 ± 0.36	28.29	21.5-37.1	82.32	54.8-125	1.16	.83-1.63
Ronnel	480	2.82 ± 0.32	32.70	26.7-40.2	95.18	58.9-156	1.01	.74-1.36
Lindane	360	3.62 ± 0.48	32.92	26.2-41.3	95.83	55.0-170	1.00	–
Dimethoate	480	3.20 ± 0.33	37.46	31.2-45.1	109.0	68.9-175	.88	.66-1.17
Methamidiphos[d]	560	1.94 ± 0.24	42.70	34.9-50.4	195.0	148-299	.78	–
Fonofos	580	2.06 ± 0.55	44.53	36.6-54.2	129.6	83.0-206	.74	.55-1.00
Carbaryl[d]	478	1.80 ± 0.20	129.2	108-155	663.7	470-1,116	.26	–
Acephate[d]	600	1.90 ± 0.20	217.0	186-252	1,023	762-1,587	.15	–
Propoxur	240		>253.8					
Chlordimeform	120		>126.9					
Methoxychlor	120		>126.9					
Cruformate	120		>126.9					
Propyl thiopyro-phosphate	120		>126.9					
Trichlorfon	120		>126.9					

[a]Values calculated from pooled data on parallel lines.

[b]µg/g body weight.

[c]Relative potency at LD_{50} and LD_{90} = LD lindane/LD candidate.

[d]Values calculated by individual probit analysis, and relative potency at LD_{50} only. Lines not parallel.

Table 2.—Analysis of variance of treatment effects

Response variable	df	Sum of squares	Mean square	F	Pr > F
PerDed-48[a]	41	10.3735	0.0405	6.25	0.0001
PertDead[b]	41	8.9735	.0119	18.34	.0001
PerDeBo[c]	41	7.2366	.1888	.93	.5874

[a]Percent mortality in beetles held for an additional 48 hours.

[b]Percent mortality of emerged beetles, corrected for 48-hour mortality.

[c]Percent mortality of beetles in the bolts.

Table 3.—Percent SPB mortality 48 hours after treatment with various insecticides

Insecticide	Concentration	Mortality[a] (mean)
	. . . . *Percent*	. . . .
Chlorpyrifos-methyl	2.0	100 a
Chlorpyrifos	2.0	92 ab
Chlorpyrifos-methyl	1.0	83 abc
Pirimiphos-ethyl	2.0	79 abcd
Chlorpyrifos	1.0	78 abcd
Carbophenothion	2.0	75 abcde
Fenitrothion	2.0	69 abcde
Pirimiphos-methyl	2.0	68 abcde
Fenitrothion	1.0	68 abcde
Permethrin	1.0	63 bcde
Phosmet (encap)	2.0	63 bcdef
Etrimphos	1.0	63 bcdef
Permethrin	.125	61 bcdef
Permethrin	.5	56 cdefg
Pirimiphos-methyl	1.0	56 cdefg
Permethrin	.25	55 cdefg
Pirimiphos-ethyl	1.0	55 cdefg
Chlorpyrifos	.50	52 defg
Chlorpyrifos-methyl	.50	51 defg
Etrimphos	2.0	50 defg
Chlorpyrifos-methyl	.25	49 defg
Lindane	.50	45 defg
Fenitrothion	.50	45 defgh
Etrimphos	.50	44 defgh
Carbophenothion	1.0	44 defgh
Pirimiphos-ethyl	.50	44 defgh
Chlorpyrifos	.25	43 defgh
Phosmet (encap)	.50	42 defgh
Phosmet (EC)	.50	35 efghi
Phosmet (EC)	2.0	32 defhi
Phosmet (encap)	1.0	27 fghi
Fenitrothion	.25	27 ghi
Pirimiphos-ethyl	.25	25 ghi
Pirimiphos-methyl	.25	23 ghi
Phosmet (EC)	1.0	22 ghi
Pirimiphos-methyl	.50	20 ghi
Carbophenothion	.50	20 ghi
Etrimphos	.25	14 hi
Phosmet (encap)	.25	14 hi
Phosmet (EC)	.25	12 hi
Control	0	7 i
Carbophenothion	.25	4 i

[a]Percentages of mortality followed by a common letter do not differ significantly at the 0.05 level according to Duncan's multiple range test.

Table 4.—Total percent mortality of SPB after treatment with various insecticides

Insecticide	Concentration	Mortality[a] (mean)
	.... *Percent*	
Chlorpyrifos-methyl	2.0	97 a
Fenitrothion	2.0	95 a
Chlorpyrifos	2.0	94 ab
Chlorpyrifos	1.0	94 ab
Fenitrothion	1.0	92 abc
Etrimphos	2.0	91 abc
Chlorpyrifos-methyl	1.0	88 abcd
Pirimiphos-ethyl	2.0	86 abcde
Etrimphos	1.0	84 abcde
Chlorpyrifos	.5	83 abcdef
Phosmet (encap)	2.0	81 abcdefg
Pirimiphos-ethyl	1.0	79 abcdefgh
Pirimiphos-methyl	2.0	76 bcdefghi
Fenitrothion	.5	76 cdefghi
Etrimphos	.5	74 defghi
Carbophenothion	2.0	74 defghi
Pirimiphos-methyl	1.0	73 defghij
Chlorpyrifos-methyl	.5	73 defghij
Permethrin	1.0	73 defghij
Phosmet (encap)	1.0	72 defghij
Phosmet (EC)	2.0	70 defghij
Chlorpyrifos-methyl	.25	67 efghijk
Chlorpyrifos	.25	67 fghijk
Fenitrothion	.25	66 fghijkl
Phosmet (EC)	1.0	66 fghijkl
Pirimiphos-ethyl	.5	64 fghijkl
Phosmet (encap)	.5	61 ghijkl
Permethrin	.25	61 hijkl
Lindane	.5	61 hijkl
Etrimphos	.25	61 hijkl
Carbophenothion	1.0	60 hijklm
Permethrin	.125	59 ijklm
Permethrin	.5	58 ijklm
Phosmet (EC)	.5	58 ijklm
Pirimiphos-methyl	.25	51 jklmn
Pirimiphos-ethyl	.25	48 klmno
Pirimiphos-methyl	.5	48 lmno
Phosmet (EC)	.25	39 mno
Phosmet (encap)	.25	39 mno
Carbophenothion	.5	31 nop
Carbophenothion	.25	24 op
Control	0	21 p

[a]Percentages followed by a common letter do not differ significantly at the 0.05 level according to Duncan's multiple range test.

Table 5.–Mean length of egg galleries in laboratory forced-attack bioassay

Treatment	Months after treatment					
	1	2	3	4	5	6
	cm					
Control	20.75	57	97	88	34	215
0.5% lindane	0	0	3.5	7.5	14.5	0
0.5% chlorpyrifos-methyl	0	0	0	5	0	44
1.0% chlorpyrifos-methyl	0	70	0	12.5	14	54

Numbers are averages of four replicates.

Table 6.–Preventive control of successful SPB attack in field bioassays of three insecticides, Georgia

Treatment	Months after treatment			
	0	2	4	6
	Percent			
Lindane	98 ± 1[a]	91 ± 6	100	90 ± 10
1% fenitrothion	91 ± 7	30 ± 36	68 ± 16	61 ± 30
2% fenitrothion	96 ± 3	84 ± 13	96 ± 3	97 ± 5
2% carbaryl (UCSF-2)	50 ± 34	–	–	–
2% carbaryl (UCSF-2)[a]	90 ± 10	75 ± 26	–	–
2% carbaryl (Sevimol 4®)[a]	61 ± 27	69 ± 6	–	–
Control[b]	47 ± 10	43 ± 10	123 ± 29	8 ± 4

[a]Replicates applied 2 months after initial carbaryl application.
[b]Numbers for controls are actual numbers of attacks.
Values shown are: 100 – (treated/control × 100).

Table 7.–Preventive control of SPB gallery production in field bioassays of three insecticides, Georgia

Treatment	Months after treatment				
	0	2	4	6	10
	Percent				
Lindane	100	100	100	100	99 ± 1
1% fenitrothion	93 ± 8	27 ± 51	50 ± 40	62 ± 46	24 ± 21
2% fenitrothion	0	0	82 ± 9	91 ± 16	81 ± 3
2% carbaryl (UCSF-2)	62 ± 23	–	–	–	–
2% carbaryl (UCSF-2)[a]	83 ± 16	50 ± 56	–	–	–
2% carbaryl (Sevimol 4®)[a]	30 ± 7	48 ± 36	–	65 ± 35	–
Control[b]	280 ± 101	246 ± 108	262 ± 49	27 ± 27	487

[a]Replicates applied 2 months after initial carbaryl application.
[b]Numbers for controls are actual lengths of egg galleries in centimeters.
Values shown are: 100 – (treated/control × 100).

Table 8.—Pesticide residues on bark at indicated times after application, Georgia

Treatment	0-day	2 months	4 months	6 months	8 months	10 months
	p/m					
Lindane	2,521	382 (15)	107 (4)	71 (3)	79 (3)	58 (2)
1% fenitrothion	3,474	1,360 (39)	984 (28)	870 (25)	738 (21)	758 (22)
2% fenitrothion	7,050	3,305 (47)	1,588 (23)	1,802 (26)	1,280 (18)	1,475 (21)
2% carbaryl (UCSF-2)	3,608	–		794 (22)	<5	
2% carbaryl (UCSF-2)[a]	4,169	2,022 (48)	–	–	–	–
2% carbaryl (Sevimol®)[a]	3,227	1,525 (47)	1,292 (40)	<5	–	–

[a]Replicates applied 2 months after initial carbaryl application.

Numbers in parentheses indicate percent of 0-day concentration.

Table 9.—Numbers of SPB trapped during 2-week periods on baited and sprayed trees at three sites, Camden County, Georgia

Site and weeks after treatment	Average number per tree					Control
	Lindane	Chlorpyrifos		Chlorpyrifos-methyl		
	0.5%	1%	2%	1%	2%	
Site 1:						
2	12.7	2.7	–	3.3	0.3	0
4	53.0	6.0	1.8	9.5	3.0	1.8
6	52.0	4.3	3.8	11.5	2.8	1.5
8	43.5	6.3	3.3	10.3	1.0	.3
10	12.8	4.0	4.5	19.8	1.0	.3
12	–	–	–	–	–	–
14	77.0	12.0	7.3	18.3	0	.8
16	36.0	3.3	.8	6.8	.8	.3
18	10.8	3.5	1.0	2.3	0	.5
20	18.0	1.3	.5	3.8	0	.5
22	6.0	2.0	3.0	6.0	.5	.2
24	10.0	3.0	.2	4.0	1.0	1.0
26	5.0	7.0	1.0	3.0	0	1.0
28	6.0	1.0	.2	2.0	.2	.5
30	8.0	2.0	2.0	4.0	.2	0
32	10.0	3.0	.2	4.0	.5	0
34	.2	.5	.5	.5	0	.5
36	2.0	.2	0	.2	0	0
38	2.0	1.0	1.0	1.0	0	0
40	0	0	0	0	0	0
42	0	0	0	0	0	0
44	0	0	1.0	.2	0	0
46	0	0	.2	.2	0	0
48	0	0	1.0	0	0	0
50	.2	0	0	0	0	0
52	.5	0	.2	0	.5	0
Site 2						
2	97.0	101.3	13.8	79.0	150.8	33.5
4	143.3	80.0	12.5	74.3	171.8	43.0
6	31.8	30.0	14.5	48.3	80.0	23.5
8	16.3	32.0	10.8	39.0	85.5	25.3
10	30.0	29.0	28.5	56.0	94.5	15.5
12	–	–	–	–	–	–

continued

Table 9. Numbers of SPB trapped during 2-week periods on baited and sprayed trees at three sites, Camden County, Georgia, continued

Site and weeks after treatment	Average number per tree					Control
	Lindane	Chlorpyrifos		Chlorpyrifos-methyl		
	0.5%	1%	2%	1%	2%	
14	15.5	35.5	46.8	73.5	114.0	6.3
16	9.0	28.8	44.8	63.0[a]	21.5	(b)
18	6.3	12.3	14.8	12.0[a]	9.0	(b)
20	8.0	37.8	54.3	53.3[a]	28.3	(b)
22	6.0	13.0	46.0	13.0	16.0	(b)
24	15.0	24.0	26.0	21.0	26.0	(b)
26	29.0	31.0	12.0	22.0	19.0	(b)
28	4.0	11.0	11.0	22.0	21.0	(b)
30	4.0	5.0	11.0	4.0	8.0	(b)
32		–	–	–	–	(b)
34	3.0	3.0	5.0	4.0	2.0	(b)
36	5.0	2.0	6.0	2.0	1.0	(b)
38	3.0	1.0	2.0	4.0	1.0	(b)
40	1.0	2.0	3.0	3.0	1.0	(b)
42	1.0	1.0	.2	1.0	.2	(b)
44	1.0	1.0	2.0	1.0	1.0	(b)
46	0	0	1.0	0	0	(b)
48	0	0	1.0	1.0	0	(b)
50	.2	.2	.2	0	.2	(b)
52	.2	1.0	2.0	1.0	1.0	(b)
Site 3:						
2	56.5	13.8	136.8	24.3	383.5	122.8
4	366.3	87.8	192.3	28.3	936.3	49.8
6	223.5	22.3	73.3	21.8	322.3	69.5
8	106.5	40.5	113.8	32.0	303.0	28.8
10	20.0	11.0	31.0	9.0	75.0	25.0
12	28.0	9.0	53.0	19.0	99.0	12.0
14	29.0	1.0	18.0	16.0	41.0	9.0
16	13.0	5.0	32.0	44.0	43.0	7.0
18	2.0	1.0	2.0	4.0	13.0	5.0
20	5.0	3.0	11.0	8.0	18.0	3.0
22	6.0	4.0	30.0	16.0	38.0	3.0[c]
24	6.0	1.0	18.0	28.0	17.0	5.0[c]
26	7.0	4.0	33.0	26.0	16.0	32.0[c]
28	3.0	2.0	11.0	10.0	8.0	6.0[c]
30	2.0	1.0	13.0	4.0	15.0	7.0[c]
32	7.0	5.0	11.0	5.0	15.0	3.0[c]
34	.5	1.0	18.0	5.0	2.0	(b)
36	1.0	.5	6.0	3.0	2.0	(b)
38	1.0	.5	2.0	.5	11.0	(b)
40	.2	1.0	1.0	1.0	.2	(b)
42	1.0	.5	1.0	1.0	0	(b)
44	–	–	–	–	–	(b)
46	–	–	–	–	–	(b)
48	0	.2	.2	0	0	(b)
50	–	–	–	–	–	(b)
52	0	0	0	0	0	(b)

[a]One tree dead.
[b]All trees dead.
[c]Three trees dead.

Table 10.—Average residues (dry weight) on bark at 4-month intervals, Camden County, Georgia

Site and treatment	0-day	4 months	8 months	12 months
	p/m			
Site 1:				
0.5% lindane	908	289 (32)	168 (18)	215 (24)
1% chlorpyrifos	2,598	1,400 (53)	1,413 (54)	648 (25)
1% chlorpyrifos-methyl	12,370	634 (27)	696 (29)	623 (26)
2% chlorpyrifos	5,027	2,122 (42)	1,170 (23)	1,467 (29)
2% chlorpyrifos-methyl	5,038	1,317 (26)	1,779 (35)	1,581 (31)
Site 2:				
0.5% lindane	1,715	328 (19)	277 (16)	214 (12)
1% chlorpyrifos	3,894	1,830 (47)	1,401 (36)	897 (23)
1% chlorpyrifos-methyl	2,605	999 (38)	701 (27)	605 (23)
2% chlorpyrifos	7,515	4,473 (59)	2,453 (33)	2,403 (32)
2% chlorpyrifos-methyl	7,996	2,557 (32)	2,723 (34)	2,010 (25)
Site 3:				
0.5% lindane	1,130	131 (12)	200 (18)	41 (4)
1% chlorpyrifos	3,448	2,077 (60)	972 (28)	687 (20)
1% chlorpyrifos-methyl	2,435	928 (38)	814 (33)	401 (16)
2% chlorpyrifos	7,674	5,645 (74)	2,307 (30)	1,731 (22)
2% chlorpyrifos-methyl	3,693	2,867 (78)	1,073 (29)	611 (16)

Numbers in parentheses indicate percent of 0-day concentration.

Table 11.—Mean days after treatment to crown-color change in six different treatments at 10 active SPB sites

Treatment	Number of trees	Days to color change[a]	Standard error
Control	40	81 a	7.6
0.5% lindane	14	167 b	14.2
1.0% chlorpyrifos-methyl	20	176 b	11.9
2.0% chlorpyrifos-methyl	19	162 b	11.6
1.0% chlorpyrifos	23	178 b	11.0
2.0% chlorpyrifos	17	182 b	12.9

[a]Includes only treatment trees whose crown color changed.

Means followed by the same letter are not significantly different. Means compared by Studentized range test (Sokal and Rohlf 1969).

Table 12.–Percent control of SPB attack by three insecticides in field bioassay

Treatment	Months after treatment							
	0	1	2	4	8	10	12	15
				Prevention of successful attack				
0.5% lindane	94[a] ± 12	88 ± 7	96 ± 8	88 ± 12	86 ± 12	68 ± 10	84 ± 10	99 ± 2
1% chlorpyrifos	88 ± 16	92 ± 8	91 ± 12	88 ± 7	66 ± 17	40 ± 8	53 ± 25	67 ± 7
2% chlorpyrifos	93 ± 16	88 ± 20	93 ± 9	88 ± 12	89 ± 14	88 ± 4	76 ± 23	91 ± 10
1% chlorpyrifos-methyl	100 ± 0	–	96 ± 4	90 ± 17	83 ± 15	–	57 ± 11	87 ± 38
2% chlorpyrifos-methyl	100 ± 0	–	100 ± 0	96 ± 4	90 ± 14	–	70 ± 39	85 ± 14
				Reduction in length of egg gallery				
0.5% lindane	98 ± 6	100 ± 0	99 ± 3	93 ± 9	99 ± 2	87 ± 4	94 ± 6	98 ± 3
1% chlorpyrifos	94 ± 7	98 ± 3	91 ± 13	85 ± 8	22 ± 93	38 ± 17	62 ± 23	37 ± 13
2% chlorpyrifos	94 ± 12	98 ± 4	96 ± 6	90 ± 11	88 ± 27	85 ± 8	77 ± 33	86 ± 12
1% chlorpyrifos-methyl	100 ± 0	–	96 ± 6	94 ± 11	100 ± 0	–	61 ± 30	51 ± 18
2% chlorpyrifos-methyl	100 ± 0	–	100 ± 0	97 ± 3	100 ± 0	–	74 ± 35	71 ± 22

[a]SD = ± 1.

Numbers represent the average of treatments made in 1975 and 1976 with four replications of one tree/replicate. Values shown are: 100 – (treated/control × 100).

Table 13.- Prevention of SPB attack and egg-gallery construction in forced-attack tests, Georgia

Treatment	Months after treatment						
	0	1	2	4	6	10	12
				Prevention of successful attack			
0.5% lindane	100 -	100 -	94 ± 10	90 -	67 -	67 ± 33	64 ± 12
1% chlorpyrifos	94 ± 10	94 ± 10	82 ± 20	80 -	60 -	50 ± 29	43 ± 20
2% chlorpyrifos	100 -	83 ± 18	94 ± 10	90 -	93 -	83 ± 29	64 ± 12
				Reduction in length of egg gallery			
0.5% lindane	100 -	100 -	100 -	100 -	65 -	79 ± 25	62 ± 25
1% chlorpyrifos	98 ± 3	98 ± 4	88 ± 2	81 -	61 -	74 ± 18	60 ± 13
2% chlorpyrifos	100 -	99 ± 2	99 ± 1	100 -	99 -	100 -	92 ± 15

Numbers are averages of four replications with one bolt/replicate. Values shown are: 100 – (treated/control × 100).

Table 14.—Average number of SPB trapped per month in the preventive study for each of four treatments and eight test sites in Mississippi during 1978–79

Site	Control	Lindane	1% fenitrothion	2% fenitrothion
13	59	88	132	127
14	26[a]	125	33	69
15	96	157	278	141
16	120	370[b] (5)	454[c] (2)	415
17	272	403	555[c] (1)	274[d] (2)
18	264	241	191[c] (2)	269
19	83	396	266[c] (3,6,4)	223
20	39[a]	92	59	168

[a]All control trees dead with the exception of three in site 14 and one in site 20; average time until death was 2.8 months.
[b]Only one tree dead; time until death was 9 months.
[c]Ten trees dead; average time until death was 7.8 months.
[d]Only one tree dead; time until death was 8 months.

Numbers in parentheses are month of highest SPB trap count on individual trees which died after insecticide treatment.

Table 15.—Comparison of hanging-bolt and standing-tree techniques for measuring preventive control of SPB by two insecticides, Mississippi, by number of months after treatment

Treatment	Trap counts		Activity in bolt bark samples	
	Bolt $\bar{X} \pm SE$	Standing tree $\bar{X} \pm SE$	Successful attacks/bolt $\bar{X} \pm SE$	Length of egg gallery (cm) $\bar{X} \pm SE$
		Zero month		
1% fenitrothion	46 ± 4	32 ± 5	10 ± 2 b	4 ± 4 b
2% fenitrothion	150 ± 34	35 ± 6	4 ± .5 b	0 b
Lindane	54 ± 18	8 ± 2	4 ± 2 b	0 b
Control	67 ± 28	10 ± 2	74 ± 17 a	230 ± 32 a
		Four months		
1% fenitrothion	55 ± 2	39 ± 6	14 ± 4 a	145 ± 2 b
2% fenitrothion	97 ± 37	136 ± 30	6 ± 1 b	45 ± 23 c
Lindane	139 ± 33	449 ± 211	2 ± 1 b	29 ± 9 c
Control	44 ± 33	Terminated	13 ± 4 a	203 ± 9 a
		Ten months		
1% fenitrothion	26 ± 8	27 ± 8	15 ± 2 b	292 ± 5 b
2% fenitrothion	43 ± 6	13 ± 3	10 ± 3 b	161 ± 20 c
Lindane	21 ± 5	22 ± 3	12 ± 5 b	85 ± 33 d
Control	32 ± 5	Terminated	42 ± 6 a	347 ± 15 a

Means followed by the same letter do not differ significantly ($P > 0.05$) in Duncan's new multiple range test.

Table 16.–Remedial control of SPB by two insecticides in Georgia and South Carolina

Treatment	Average number SPB per bolt/1,000 cm²			Average % mortality			Average emergence per bolt
	Larvae	Pupae	Adult	Larvae	Pupae	Adult	
Control	51 ± 54	13 ± 15	17 ± 12	18 ± 37	39 ± 42	17 ± 15	123 ± 89
0.5% lindane	49 ± 85	6 ± 9	29 ± 17	8 ± 9	40 ± 56	69 ± 60	19 ± 4
0.5% chlorpyrifos	92 ± 71	36 ± 38	26 ± 13	12 ± 11	27 ± 27	47 ± 57	127 ± 11
1% chlorphyrifos	54 ± 75	9 ± 13	27 ± 19	15 ± 19	48 ± 77	71 ± 76	24 ± 8
2% chlorpyrifos	22 ± 46	6 ± 10	38 ± 16	29 ± 33	62 ± 95	73 ± 26	31 ± 10

Numbers are averages of 14 replications ± 1 SD.

Table 17.–Emergence and survival of SPB from bolts treated with remedial insecticides in August and November, 1978, Georgia

Treatment and replicate	Total SPB emergence	Mean daily emergence	Survival (hours after emergence)		
			24	48	72
	. . . *Number* . . .		. . . . *Percent*		
			August 1978		
Check:					
1	491	6.6	90.3	86.3	88.5
2	1,056	25.1	98	95.7	91
3	455	10.8	90.5	88	78
4	457	10.9	97	94.3	92.5
Lindane					
1	83	2	54	34.5	7.5
2	35	.87	90	57.7	25
3	43	1.03	36.5	13	0
4	55	1.3	81	50	30
1% fenitrothion:					
1	78	1.83	10	8.5	0
2	14	.33	3.5	3.5	0
3	35	.8	7.5	14	0
4	37	.87	24.5	7	0
2% fenitrothion:					
1	53	1.27	5	7	0
2	43	1.03	24.5	3.5	0
3	38	.9	6.5	0	
4	49	1.17	.5	0	
			November 1978		
Check:					
1	910	21.66 ± 32	96	86	77
2	235	5.57 ± 8	98	89	83
3	244	5.98 ± 15	94	88	80
4	165	3.93 ± 6	93	81	74
Lindane					
1	22	.53 ± .9	32	12	4
2	20	.47 ± 1	32	14	9
3	28	.69 ± 2	14	9	1
4	4	.067 ± 0.5	100	100	100
1% fenitrothion:					
1	1	.027 ± 0.15	0	--	
2	0	0			
3	320	8.27 ± 12	1	.1	1
4	183	4.33 ± 7	19	19	18
2% fenitrothion:					
1	10	.28 ± 0.53	11	-	
2	4	.067 ± 0.62	0	-	-
3	23	.53 ± 1.6	0	-	
4	69	1.67 ± 3	19	7	7

Table 18.—Emergence and percent survival of SPB from infested test bolts treated with two insecticides, Mississippi

Treatment	Emergence		$\bar{X} \pm SE$		
	$\bar{X} \pm SE$[a]	Total	Alive at collection (0–24 hours)[b]	Survival after 24 hours (24–48 hours)[c]	Survival after 48 hours (48–72 hours)
			Percent		
		First 14 days			
Control	249 ± 65	(7,470)	19.4 ± 4.6	3.9 ± 3.6	0
Lindane	164 ± 94	(997)	9.2 ± 4.1	.5 ± .3	0
1% fenitrothion	695 ± 583	(2,084)	7.0 ± 5.0	.4 ± .4	0
		Next 17 days			
Control	176 ± 122	(527)	36.5 ± 12.3	18 ± 18	0
Lindane	187 ± 115	(561)	16.8 ± 1.9	2.4 ± 1.4	0
1% fenitrothion	247 ± 139	(772)	9.1 ± 3.0	1.7 ± 1.7	0
2% fenitrothion	292 ± 238	(876)	8.5 ± 6.3	.1 ± 0.1	0

[a]Three replications for a total of nine trees per treatment, three 0.5-m bolts/tree.
[b]% survival is average of number alive ÷ total emerged/replication.
[c]24-hour error possible due to only one check/day.

Table 19.—Number of SPB before treatment and after emergence from bolts treated with chlorpyrifos, compared with lindane, Louisiana

Treatment	Total No. of emerging beetles	Avg. No. of brood/ 0.09 m^2 before treatment	Avg. No. of emerging beetles/ 0.09 m^2	% beetles emerging from treatments
Control	9,885	196	125	64
Lindane	2,309	256	29	11
Chlorpyrifos:				
2%	1,565	263	21	8
1%	1,719	298	24	8
0.5%	3,275	221	46	21

Table 20.—Effect of simulated rain on loss of lindane and chlorpyrifos-methyl from pine bark

Treatment and wash time after application	Gallons water/0.09 m^2 of bark used as wash	% loss based on nonwashed controls
0.5% lindane (EC),		
10 minutes	0.33	17
10 minutes	1.67	26
2 hours	.33	0
2 hours	1.67	3
0.5% lindane (WP),		
10 minutes	.33	30
10 minutes	1.67	51
2 hours	.33	0
2 hours	1.67	22
1% chlorpyrifos-methyl (EC),		
10 minutes	.33	36
10 minutes	1.67	58
2 hours	.33	34
2 hours	1.67	46

Table 21. Schedule for collecting cloth residue samples through surface contact with chlorpyrifos-treated bark

Treatment	No. of replications	
	1-unit area[a]	3-unit area[a]
0.5% wet	2	2
0.5% dry	2	2
1% wet	4	4
1% dry	4	4
2% wet	4	4
2% dry	4	4
Control	3	3

[a]Unit area represents 1 ft^2 (0.09 m^2) surface area contacted.

Wet–immediately after treatment when bark is still wet; Dry–approximately 2 hours after treatment when bark has dried.

Table 22.–Persistence of insecticides on bark of standing loblolly pines

Treatment	Initial concentration	Months after treatment							
		1	2	4	6	8	10	12	15
	p/m	*Percent of initial concentration*							
Lindane:									
0.5%	745 ± 266[a]	46 ± 10	28 ± 9	9 ± 4	5 ± 3	8 ± 7	5 ± 5	5 ± 4	6 ± 2
Chlorpyrifos:									
1%	1,449 ± 574	50 ± 3	58 ± 31	46 ± 20	37 ± 12	32 ± 14	32 ± 16	29 ± 14	18 ± 13
2%	3,192 ± 1,110	50 ± 6	59 ± 23	44 ± 17	33 ± 8	28 ± 13	26 ± 10	22 ± 9	14 ± 2
Chlorpyrifos-methyl:									
1%	2,374 ± 431	–	47 ± 10	31 ± 6	22 ± 5	19 ± 7	19 ± 7	13 ± 1	9 ± 2
2%	4,738 ± 824	–	43 ± 8	28 ± 9	28 ± 2	17 ± 7	27 ± 6	11 ± 5	8 ± 2

[a]± 1 SD.

Numbers represent the average of treatments made in 1975 and 1976 with four replications of one tree/replicate.

Table 23.–Residue levels of insecticides at indicated times after treatment

Treatment	0-day	2 months	4 months	6 months	8 months	10 months
	p/m					
Lindane	2,521	382 (15)	107 (4)	71 (3)	79 (3)	58 (2)
1% fenitrothion	3,474	1,360 (39)	984 (28)	870 (25)	738 (21)	758 (22)
2% fenitrothion	7,050	3,305 (47)	2,203 (31)	1,802 (26)	1,280 (18)	1,475 (21)
2% carbaryl (UCSF-2)	3,608	–	–	794 (22)	< 5	–
2% carbaryl (UCSF-2)[a]	4,169	2,022 (48)	–	–	–	–
2% carbaryl (Sevimol 4®)[a]	3,227	1,525 (47)	1,292 (40)	<5	–	–

[a]Replicates applied 2 months after initial carbaryl application.

Numbers in parentheses are percentages of 0-day concentration.

Table 24.–Effect of adjuvants on persistence of insecticides on bark of loblolly pines at indicated times

Insecticide and adjuvant	2 months	4 months	6 months	9 months
	Percent of initial concentration			
5% lindane:				
+ Exhalt®	31 ± 3	12 ± 2	9 ± 1	9 ± 1
+ Nu-Film 17®	37 ± 8	16 ± 3	10 ± 1	7 ± 2
+ Plant Gard®	39 ± 2	16 ± 2	12 ± 2	7 ± 2
+ Plyac®	36 ± 15	25 ± 12	20 ± 2	15 ± 0
+ Stretcher®	34 ± 5	16 ± 3	15 ± 2	8 ± 2
+ Triton®	28 ± 8	16 ± 9	11 ± 1	4 ± 0
- Control	34 ± 0	10 ± 1	9 ± 1	8 ± 2
1% chlorpyrifos:				
+ Exhalt®	49 ± 3	43 ± 17	40 ± 18	22 ± 6
+ Nu-Film 17®	66 ± 17	42 ± 19	37 ± 12	31 ± 7
+ Plant Gard®	51 ± 10	25 ± 2	24 ± 1	23 ± 11
+ Plyac®	45 ± 11	37 ± 12	29 ± 4	22 ± 2
+ Stretcher®	67 ± 12	37 ± 8	33 ± 8	21 ± 2
+ Triton®	73 ± 9	45 ± 2	40 ± 1	29 ± 1
- Control	65 ± 18	34 ± 15	31 ± 5	24 ± 1

Numbers are averages of three replications with one tree/replicate.

Table 25.–Comparative distribution of lindane downwind from each of three spray-delivery systems

Distance from source (meters)	John Bean	Delavan foam	Accutrol foam
		μg *lindane/cm*^{2}	
5	0.02	0.08	0.04
10	11.03	0.59	0.07
15	6.75 ± 8.75	13.03 ± 8.54	12.33 ± 12.16
20	10.23 ± 10.11	6.11 ± 7.18	11.66 ± 16.25
25	5.22 ± 3.22	.50 ± 0.36	.35 ± 0.30
30	.78 ± 0.65	.15 ± 0.12	.10 ± 0.10
35	.11 ± 0.03	.27 ± 0.14	.06 ± 0.05
40	.07 ± 0.04	.22 ± 0.24	.03 ± 0.02
45	.04 ± 0.003	.01 ± 0.01	.15 ± 0.13
50	.01 ± 0.0004	.01 ± 0.01	.01 ± 0.003

Numbers are averages of three replications ± 1 SD for distances from 15 through 40 m, one replication for 5 and 10 m, and two replications for 45 and 50 m.

Table 26.–Cloth residue analysis for chlorpyrifos

Treatment	Louisiana		Georgia	
	Wet	Dry	Wet	Dry
		mg/0.09 m²		
2 percent:				
(1)	53.2	1.7	65.7	9.9
(3)	27.3	1.0	59.8	9.6
1 percent:				
(1)	16.4	1.8	27.3	4.0
(3)	10.2	1.4	13.1	2.7
0.5 percent:[a]				
(1)	3.6	.9	–	–
(3)	1.9	.5	–	–

[a] Averages based on two replications.

Wet samples rubbed 5 minutes after spraying; dry samples, 2 hours after spraying.

Numbers in parentheses represent units of area (0.09 m^2) of bark rubbed with cloth. Residue is reported as 0.09 m^2; therefore, residue for three units rubbed is not total mg of residue in cloth sample.

Table 27.–Characteristics of soils in studies on effect of chlorpyrifos and fenitrothion on soil microbial populations

Soil No.	Carbon	Organic matter	Total nitrogen
	Percent		*p/m*
1	4.26	7.33	1,440
2	1.04	1.78	4,339
3	1.14	1.97	435
4	1.03	1.77	419
5	.77	1.33	339
6	1.84	3.16	704

Table 28.–Effect of fenitrothion on soil microbial populations

Soil No.	Mean ± SD				
	0 p/m	1 p/m	10 p/m	50 p/m	100 p/m
	Mean No. of fungal propagules/g soil × 10^2 (average of 10 replicates)				
2	708bc ± 251	968ab ± 458	1,072a ± 485	735bc ± 132	642c ± 112
3	1,317a ± 460	1,135a ± 385	995a ± 648	1,302a ± 278	1,070a ± 558
4	642a ±328	515ab ± 228	570ab ± 305	505ab ± 110	335b ± 165
5	428a ± 128	588a ± 200	507a ± 248	505a ± 240	590a ± 278
6	322c ± 205	562b ± 238	792a ± 232	910a ± 202	800a ± 165
Average	682a ± 388	752a ± 280	788a ± 250	792a ± 332	692a ± 265
	Mean No. of bacteria/g soil × 10^3 (average of 12 replicates)				
1	410b ± 198	407b ± 205	655ab ± 252	745a ± 505	448b ± 185
2	795a ± 722	442a ± 318	448a ± 355	935a ± 1,448	637a ± 438
3	758ab ± 488	1,182a ± 752	440b ± 265	670b ± 318	795ab ± 370
5	95b ± 88	238ab ± 155	132b ± 102	132b ± 57	380a ± 280
6	162b ± 58	148b ± 62	230ab ± 185	305a ± 242	155b ± 110
Average	445a ± 325	484a ± 409	381a ± 205	558a ± 330	483a ± 245

For each soil, numbers with the same letters are not significantly different in Duncan's multiple range test ($P = 0.05$).

Table 29.—Effect of chlorpyrifos on soil microbial populations

Soil No.	Mean ± SD				
	0 p/m	1 p/m	10 p/m	50 p/m	100 p/m
	Mean No. of fungal propagules/g soil × 10^2 (average of 15 replicates)				
2	1,120a ± 468	628b ± 260	475bc ± 188	435bc ± 165	238c ± 98
3	1,282a ± 198	1,448a ± 419	1,718a ± 642	1,390a ± 542	1,410a ± 518
5	430ab ± 250	540ab ± 320	318b ± 182	610a ± 385	400ab ± 260
Average	544a ± 453	872a ± 500	837a ± 767	812a ± 508	682a ± 635
	Mean No. of bacteria/g soil × 10^3 (average of 15 replicates)				
2	531b ± 344	1,197a ± 492	581ab ± 518	556b ± 387	481b ± 266
3	538a ± 466	506a ± 441	697a ± 380	581a ± 380	306a ± 294
4	219ab ± 107	106b ± 40	216ab ± 90	409a ± 343	338a ± 247
Average	420a ± 175	602a ± 552	560a ± 302	518a ± 92	375a ± 92

For each soil, numbers with the same letters are not significantly different in Duncan's multiple range test ($P = 0.05$).

Table 30.—Effect of insecticides on mean numbers of soil fungal propagules/g through time

Insecticide and concentration (p/m)	Days of incubation		
	1	7	14
	Hundreds of propagules[a]		
Fenitrothion:			
0	675 b	1,160 a	1,410 ab
1	730 b	1,160 a	1,100 bc
10	810 b	1,020 a	1,910 a
50	805 b	1,005 a	750 c
100	1,105 a	885 a	645 c
Chlorpyrifos:			
0	1,015 d	965 de	1,380 d
1	1,360 d	750 ef	1,275 d
10	1,109 d	1,130 d	1,420 d
50	1,095 d	495 f	1,170 d
100	1,015 d	730 ef	930 d

[a]Each value is the average of five replicates.

Numbers with the same letter do not differ significantly according to Duncan's multiple range test ($P = 0.05$).

Table 31.—Radioactivity from chlorpyrifos-treated soil fungus cultures after indicated times of incubation

Fungus	7 days		14 days		28 days	
	Organic	Aqueous	Organic	Aqueous	Organic	Aqueous
	Percent					
Control	89 (61)	11 (8)	81 (23)	19 (5)	73 (22)	27 (8)
Trichoderma harzianum	85 (58)	15 (10)	76 (27)	24 (9)	83 (4)	17 (1)
Penicillium multicolor	79 (49)	21 (13)	84 (30)	16 (6)	54 (2)	46 (1)
P. vermiculatum	84 (54)	16 (10)	73 (29)	27 (11)	50 (5)	50 (5)
Mucor sp.	76 (51)	24 (16)	68 (10)	32 (5)	20 (4)	80 (14)

Numbers are the average of three replicates. Those outside the parentheses are based on recovered radioactivity. Those inside parentheses are based on initial radioactivity.

Table 32.—Effects of lindane and chlorpyrifos-methyl on litter mesofauna

Time and treatment	Organisms						
	Orbatid	Mesostigmatid	Trombidiform	Collembolan	Others	Total mites	Total
	No./20 cm² litter area[a]						
Before treatment:							
0.5% lindane	104	2	68	16	2	174	192
0.5% chlorpyrifos-methyl	128	2	78	23	2	208	233
1% chlorpyrifos-methyl	191	6	183	26	4	380	410
Control	135	5	146	26	4	336	366
1 week after treatment:							
0.5% lindane	55	1.1	41*	3.9	0.6*	105*	110*
0.5% chlorpyrifos-methyl	67	1.1	40*	4.6	.5*	115*	120*
1% chlorpyrifos-methyl	102*S	1.5	58*	4.4	1.1*	154*	159*
Control	52	1.3	241	7.9	2.4	285	296
6 weeks after treatment:							
0.5% lindane	130	5.8	73*S	13*	2.2	225	241
0.5% chlorpyrifos-methyl	125	1.7*	43	11*	2.4	185	197
1% chlorpyrifos-methyl	164	5.3	50	17*	2.0	209	228
Control	152	7.2	33	32	3.2	172	207
23 weeks after treatment:							
0.5% lindane	136	7.5	25	9.7*	3.4	168	182
0.5% chlorpyrifos-methyl	145	4.1	19	6.5*	.6*	171	178
1% chlorpyrifos-methyl	164	4.2	25	7.0*	1.7*	201	208
Control	121	4.9	32	27	4.2	148	179
75 weeks after treatment:							
0.5% lindane	109*S	5.7	24	19	5.1*S	139*S	163*S
0.5% chlorpyrifos-methyl	97*S	6	20	9.8*	1.1*	125	136
1% chlorpyrifos-methyl	100*S	4.6*	31*S	9.1*	2.9	137*S	148
Control	65	7.9	23	18	3.0	94	115

[a]Means are adjusted for covariates (pretreatment counts and moisture content) for an average of 30 samples.

*Significantly different from control ($P = 0.05$), S indicates stimulation using Dunnett's test comparing each treatment effect with control.

Table 33.—Effects of lindane and chlorpyrifos-methyl on soil mesofauna

Time and treatment	Organisms						
	Orbatid	Mesostigmatid	Trombidiform	Collembolan	Others	Total mites	Total
	No./20 cm^2 soil area[a]						
Before treatment:							
0.5% lindane	109	2	43	38	4	154	196
0.5% chlorpyrifos-methyl	66	1	66	36	3	133	172
1% chlorpyrifos-methyl	82	2	40	32	2	124	158
Control	44	1	16	20	1	61	82
1 week after treatment:							
0.5% lindane	43	1.2	27	16	2.5	72	90
0.5% chlorpyrifos-methyl	73	1.1	29	23	2.2	99	124
1% chlorpyrifos-methyl	76	1.1	18	23	2.2	96	121
Control	59	1.2	23	17	1.7	87	106
6 weeks after treatment:							
0.5% lindane	49	1.5*	15	11*	3.1	66	82
0.5% chlorpyrifos-methyl	40	1.7*	23*S	12*	2.6	61	76
1% chlorpyrifos-methyl	34	1.2*	16	19	1.4	52	72
Control	47	2.8	11	21	1.9	64	83
23 weeks after treatment:							
0.5% lindane	71*S	3.7*S	12	9.4*	2.2*	82	95
0.5% chlorpyrifos-methyl	56	5.6*S	17	11*	1.1*	79	92
1% chlorpyrifos-methyl	40	3.0	9	9.5*	1.1*	51	61
Control	41	1.3	14	16	12	61	88
75 weeks after treatment:							
0.5% lindane	54*S	1.4	8.2	5.9	1.9	63	72
0.5% chlorpyrifos-methyl	60*S	1.0	12	7.8	1.5	72*S	82*S
1% chlorpyrifos-methyl	46	1.2	12	10	1.7	60	72
Control	32	.9	6.3	9.0	1.3	40	48

[a]Means are adjusted for covariates (pretreatment counts and moisture content) for an average of 30 samples.

*Significantly different from control ($P = 0.05$); S indicates stimulation using Dunnett's test comparing each treatment effect with control.

Table 34. Insecticide residues in soil and litter mesofauna tests

Time after spraying and treatment	Litter			Soil		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range
	p/m					
1 day:[a]						
0.5% lindane	9.4 ± 9.6	7.6	19.0		–	–
0.5% chlorpyrifos-methyl	21.1 ± 29.9	5.0	52.8	–	–	–
1% chlorpyrifos-methyl	14.8 ± 9.8	10.3	18.1	–	–	–
1 week:[b]						
0.5% lindane	8.8 ± 7.9	4.4	28.4	0.16 ± 0.07	0.1	0.16
0.5% chlorpyrifos-methyl	30.1 ± 21.1	21.0	66.3	3.05 ± 2.75	2.38	8.1
1% chlorpyrifos-methyl	33.9 ± 32.5	18.0	115.4	4.41 ± 1.88	3.79	6.1
5 months:						
0.5% lindane	2.02 ± 2.93	.6	11.0	<0.1		–
0.5% chlorpyrifos-methyl	8.06 ± 21.7	.6	85.4	<0.1	–	–
1% chlorpyrifos-methyl	.98 ± 1.02	.6	3.24	<0.1	–	–

[a] Average of three replicates.

[b] Average of 15 replicates in litter and 10 replicates in soil.

Table 35.—Efficacy of partial tree-bole sprays

Spray coverage	Number of trees		
	Treated	Attacked	Killed
		Spray applied during 1979[a]	
Full bole	16	2	1[b]
Below 6.5 m	16	15	15
Below 2.0 m	12	12	12
Unsprayed check	12	12	12
		Spray applied during 1980[c]	
Full bole	5	0	0
Above 5 m	23	2	1
Below 5 m	7	7	7
Unsprayed check	11	11	11

[a]Trees were 20 m in height; half were sprayed with 2% chlorpyrifos, half with 0.5% lindane.

[b]Residue analysis indicated this tree was not sprayed.

[c]Trees were 17 m in height; all were sprayed with 0.5% lindane.

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1981. Field and laboratory evaluations of insecticides for southern pine beetle control. USDA For. Serv., Gen. Tech. Rep. SE-21, 40 p. Southeast. For. Exp. Stn., Asheville, N.C.

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KEYWORDS: *Dendroctonus frontalis*, efficacy, microbial degradation, phytotoxicity, adjuvants, lindane, chlorpyrifos, chlorpyrifos-methyl, fenitrothion.

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Reports results of laboratory screenings and field studies of insecticides for use against the southern pine beetle. Preventive as well as remedial efficacy were observed, along with phytotoxicity to pine and understory hardwood species, effects of insecticides on soil microbial and mesofaunal populations, and degradation of insecticides by selected soil microbes.

KEYWORDS: *Dendroctonus frontalis*, efficacy, microbial degradation, phytotoxicity, adjuvants, lindane, chlorpyrifos, chlorpyrifos-methyl, fenitrothion.

The Forest Service, U.S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.